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A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Rainwater Basin Depressional Wetlands in Nebraska

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Ecosystem Management and Restoration Research Program

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ABSTRACT: The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of wetland functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act, Section 404 Regulatory Program, permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of wetland restoration projects, and management of wetlands

This report uses the HGM Approach to develop a Regional Guidebook to (a) characterize ponded, herbaceous marshes on the loess plain of south-central Nebraska, (b) provide the rationale used to select functions of ponded, herbaceous depressional marsh subclass, (c) provide the rationale used to select model variables and metrics, (d) provide the rationale used to develop assessment models, (e) provide data from reference wetlands and document its use in calibrating model variables and assessment models, and (f) outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

Corps of Engineers Research Report Summary, May 2004

Assessing Wetland Functions

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Rainwater Basin Depressional Wetlands in Nebraska (ERDC/EL TR-04-4)

ISSUE: Section 404 of the Clean Water Act directs the U.S. Army Corps of Engineers to administer a regulatory program for permitting the discharge of dredged or fill material in "Waters of the United States." As part of the permit review process, the impact of discharging dredged or fill material on wetland functions must be assessed. On 16 August 1996, a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) for developing Regional Guidebooks to assess wetland functions was published.

RESEARCH OBJECTIVE: The objective of this research was to develop a Regional Guidebook for applying the Hydrogeomorphic Approach to depressional wetlands in Nebraska in the context of the 404 Regulatory Program.

SUMMARY: The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified, including: determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

AVAILABILITY OF REPORT: The report is available at the following Web sites: http://www.wes.army.mil/el/wetlands/wlpubs.html or http://libweb.wes.army.mil/index.htm. The report is also available on Interlibrary Loan Service from the U.S. Army Engineer Research and Development Center (ERDC) http://libweb.wes.army.mil/lib/library.htm.

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Preface

This Regional Guidebook was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Ecosystem Management and Restoration Research Program (EMRRP). It is published as an Operational Draft for field testing for a 2-year period. Comments should be submitted via the Internet at the following address: *http://www.wes.army.mil/el/wetlands/hgmhp.html*. Written comments should be addressed to :

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Commander and Executive Director of ERDC was COL James R. Rowan, EN. Director was Dr. James R. Houston.

1 Introduction

Background

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods used to develop and apply functional indices to the assessment of wetlands. The approach was initially designed for use in the Clean Water Act Section 404 Regulatory Program including: reviewing permits to consider alternatives, minimizing impacts, assessing unavoidable project impacts, determining mitigation requirements, and monitoring the success of mitigation projects. However, a variety of other potential applications for the approach have been identified including: determining minimal effects under the Food Security Act, designing mitigation projects, and aiding in wetlands restoration and management.

On June 20, 1997, the National Action Plan (NAP) to implement the HGM Approach was published (National Interagency Implementation Team 1997). The NAP was developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), Natural Resources Conservation Service (NRCS), Federal Highways Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). Publication of the NAP was designed to outline a strategy and promote the development of Regional Guidebooks for assessing the functions of regional wetland subclasses using the HGM Approach, solicit the cooperation and participation of Federal, State, and local agencies, academia, and the private sector in this effort, and update the status of Regional Guidebook development.

The preparation of a guidebook for Rainwater Basin wetlands was initiated in advance of publication of the NAP. Although the sequence of tasks necessary to develop a Regional Guidebook had not yet been formally published, the proper tasks as outlined in the NAP were followed for the Rainwater Basin Depressional Wetlands Guidebook (pages 9 and 10).

An initial developmental workshop was held in Lincoln, Nebraska, May 28 and 29, 1996. Attendees included hydrologists, bio-geochemists, soil scientists, wildlife biologists, and plant ecologists with extensive knowledge of Nebraska's wetlands. Based on the results of the workshop, a regional wetland subclass was defined and characterized, a reference domain was defined, wetland functions were selected, model variables were identified, and conceptual assessment models were developed. Subsequently, field work was conducted to collect data from reference wetlands in 1996 and 1997. These data were used to revise and calibrate the conceptual assessment models. A draft version of this Regional Guidebook was then subjected to several rounds of peer review. Finally, a training workshop was conducted July 25 through 28, 2000, and comments from participants were incorporated into the present document.

Objectives

The objectives of this Regional Guidebook are to: (a) characterize the depressional wetlands in the Rainwater Basin Region of south-central Nebraska, (b) provide the rationale used to select functions for this depressional regional subclass, (c) provide the rationale used to select model variables and metrics, (d) provide the rationale used to develop assessment models, (e) provide data from reference wetlands and document its use in calibrating model variables and assessment models, and (f) outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

Organization

This document is organized in the following manner: Chapter 1 provides the background objectives and organization of the document. Chapter 2 provides a brief overview of the major components of the HGM Approach and the Development and Application Phases required to implement the approach. Chapter 3 characterizes the Rainwater Basin depressional wetlands subclass in south-central Nebraska in terms of geographical extent, climate, geomorphic setting, hydrology, vegetation, soils, and other factors that influence wetland function. Chapter 4 discusses each of the wetland functions, model variables, and functional indices. This discussion includes a definition of the function, a quantitative, independent measure of the function for the purposes of validation, a description of the wetland ecosystem and landscape characteristics that influence the function, a definition and description of model variables used to represent these characteristics in the assessment model, a discussion of the assessment model used to derive the functional index, and an explanation of the rationale used to calibrate the index with reference wetland data. Chapter 5 outlines the steps of the assessment protocol for conducting a functional assessment for the Rainwater Basin depressional wetlands subclass. Appendix A contains a glossary. Appendix B provides summaries of functions, assessment models, variables, variable measures, and copies of the field forms needed to collect field data. Appendix C contains miscellaneous data collected at reference wetlands. While it is possible to assess the functions of the Rainwater Basin depressional wetlands subclass in south-central Nebraska using only the information contained in Chapter 5 and Appendix B, it is suggested that potential users familiarize themselves with the information in Chapters 1 through 4 prior to conducting an assessment.

2 Overview of the Hydrogeomorphic Approach

The HGM Approach to Wetland Functional Assessment is a collection of concepts and methods that are used to develop and apply functional indices to the assessment of wetlands. The HGM Approach includes four integral components: (a) HGM Classification, (b) Reference Wetlands, (c) Assessment Models and Functional Indices, and (d) Application Protocols. The four components of the HGM Approach are integrated into a Regional, Subclass-specific Guidebook, similar to this document. In the Development Phase of the HGM Approach, research scientists and regulatory managers work cooperatively to select a list of functions and indicators of function that will best represent the functional range of variation among wetlands of the subclass and region. Data are gathered by an Assessment Team (A-Team) from an array of wetlands that represent that range of variation and establish a data set of Reference Wetlands. The functional models and data are combined along with field protocols and methods for analysis to formulate the Regional Guidebook. The end-users then employ the Regional Guidebook during the Application Phase to conduct HGM functional assessments on project wetlands. Each of these components of the HGM Approach are discussed briefly below. More extensive discussions of these topics can be found in Brinson (1993, 1995a, b), Brinson et al. (1995), Brinson et al. (1996), Brinson et al. (1998), Clairain et al. (2002), Davis (in preparation a, b), Hauer and Smith (1998), Smith et al. (1995), Smith (2001a, b), Smith and Wakeley (2001), and Wakeley and Smith (2001).

Hydrogeomorphic Classification

Wetland ecosystems share a number of characteristics including periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these shared characteristics, they occur under a wide range of climatic, geologic, and physiographic situations, and exhibit a wide variety of physical, chemical, and biological characteristics on both spatial and temporal scales (Middelton 1999; van der Valk 1989; Mitsch and Gosselink 1993; Semeniuk 1987; Cowardin et al. 1979). This variability presents a challenge to the development of assessment methods that are both accurate in the sense that the method detects significant change in function, and practical in the sense the method can be carried out in the relatively short time frame that is generally available for conducting assessments. Broad scale methods, designed to assess multiple wetland types lack the resolution necessary to detect significant changes in function. Consequently, one way to achieve an appropriate level of resolution within the available time frame is to apply the model to similar classes of wetlands (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993). It identifies groups of wetlands that perform similarly using three criteria that fundamentally influence how wetlands function. These criteria are geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the land form and position of the wetland in the landscape. Water source refers to the primary inputs of the water to the wetland such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland.

Based on these three criteria, any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale Brinson (1993) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995).

Table 1
Hydrogeomorphic Wetland Classes at a Continential Geographic Scale

HGM Wetland	Definition
Depression	Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or may be closed basins that lack them completely. The water source may come from one or any combination of the following: precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression, but may come from a deep aquifer, or subsurface springs. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water as evapotranspiration, through intermittent or perennial outlets, or as recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depression wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and river flow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are a common example of tidal fringe wetlands.
	(Continued)

Table 1 (Concluded)	
HGM Wetland	**Definition**
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands integrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.
Slope	Slope wetlands are found in association with the discharge of groundwater to the land surface, or at sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from very gentle to steep. The predominant source of water is groundwater or interflow discharging to the land surface. Direct precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression, and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are a common example of mineral soil flat wetlands.
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats, in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are common examples of organic soil flat wetlands.
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional water sources may be interflow or occasional overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In the headwaters, riverine wetlands often intergrade with slope or depressional wetlands as the channel (bed) and bank disappear, or they may intergrade with poorly drained flats or uplands. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwood floodplains are a common example of riverine wetlands.

In many cases, the level of variability in wetlands encompassed by a continental-scale hydrogeomorphic class is still too great to develop assessment models that can be rapidly applied while being sensitive enough to detect changes in function at a level of resolution appropriate to the majority of application needs. For example, at a continental geographic scale, the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud et al. 1989; Hubbard 1988), playa lakes in the High Plains of Texas (Bolen et al. 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953; Ewel and Odum 1984).

To reduce both inter- and intra-regional variability, the three classification criteria can be applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (Stewart and Kantrud 1971; Golet and Larson 1974; Wharton et al. 1982; Ferren et al. 1996a, b). Regional subclasses, like the continental classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing subclasses in certain regions. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water), or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Examples of potential regional subclasses are shown in Table 2. Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Table 2
Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics (adapted from Smith et al. 1995)

Geomorphic Setting	Dominant Water Source	Dominant Hydrodynamics	Potential Regional Wetland Subclasses	
			Eastern USA	Western USA/Alaska
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidriectional, horizontal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (organic soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizontal	Bottomland hardwood forests	Riparian wetlands

Reference Wetlands

Reference wetlands are the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, fire, erosion, and sedimentation) as well as human alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always the case because of time and resource constraints.

Reference wetlands serve several purposes:

a. They establish a basis for defining what constitutes a characteristic, sustainable level of function across the suite of functions selected for a regional wetland subclass.
b. They establish the range and variability of conditions exhibited by model variables.
c. They provide the data necessary for calibrating model variables and assessment models.
d. They provide a physical representation of wetland ecosystems that can be repeatedly observed and measured.

Reference standard wetlands are the subset of reference wetlands that perform the functions selected for a regional subclass at a level that is characteristic in the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

Table 3
Reference Wetland Terms and Definitions (Smith et al. 1995)

Term	Definition
Reference domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected.
Reference wetlands	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alteration.
Reference standard wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human altered wetland sites in the least human altered landscapes. By convention, the functional capacity index for all functions in reference standard wetlands are assigned a 1.0.
Reference standard wetland variable condition	The range of conditions exhibited by model variables in reference standard wetlands. By convention, reference standard conditions receive a variable subindex score of 1.0.
Site potential (mitigation project context)	The highest level of function possible given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass.
Project target (mitigation project context)	The level of function identified or negotiated for a restoration or creation project.
Project standards (mitigation context)	Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project target is not being achieved.

Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. It defines the relationship between one or more characteristics or processes of the wetland ecosystem or surrounding landscape, and the functional capacity of a wetland ecosystem. Functional capacity is the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands. Model variables represent the characteristics of the wetland ecosystem and surrounding landscape that influence the capacity of a wetland ecosystem to perform a function. Model variables are ecological quantities that consist of five components (Schneider 1994). These include: (a) a name, (b) a symbol, (c) a measure of the variable and procedural statement for quantifying or qualifying the measure directly, or calculating it from other measurements, (d) a set of values (i.e., numbers, categories, or numerical estimates (Leibowitz and Hyman 1997) that are generated by applying the procedural statement, and (e) units on the appropriate measurement scale. Table 4 provides several examples from Hauer et al. (2002).

Table 4
Components of a Model Variable (after Hauer et al. 2002)

Name (Symbol)	Measure/Procedural Statement	Resulting Values	Unit (Scale)
Sediment Delivery (V_{sed})	Potential for sediment delivery to the wetland. Visually determine soil grain size, measure slopes, distances of surrounding uplands, and determine land use.	Continuous from 0 to >100	unitless (nominal scale)
Duration of Inundation (V_{durat})	Average number of weeks per year that the wetland is inundated (flooded) with water. Measured directly or may be estimated based on vegetation indicators or Cowardin et al. (1979) classification	0 to 52 weeks	weeks (interval scale)
Percent Coverage by Native vs. Non-Native Plants (V_{npcov})	Percentage of each plant community within each wetland zone that is occupied by native plants.	0 to 100	% (scale)

Model variables occur in a variety of states or conditions in reference wetlands. The state or condition of the variable is denoted by the value of the measure of the variable. Based on the wetland's condition (i.e., value of the metric), model variables are assigned a variable subindex score. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex score of 1.0 is assigned. As the condition of a variable deviates from the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex score reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex score drops to zero. In other cases, the subindex score for a variable never drops to zero.

Model variables are combined in an assessment model to produce a Functional Capacity Index (FCI) that ranges from 0.0 to 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the function at a level that is characteristic of reference standard wetlands. Decrease in the FCI indicates the capacity of the wetland to perform the function is less than that which is characteristic of reference standard wetlands (Smith and Wakeley 2001).

Assessment Protocols

The final component of the HGM Approach is the assessment protocol, which consists of specific instructions that allow the end user to assess the functions of a particular wetland area using the functional indices in the Regional Guidebook. The first task is characterization, which involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for model variables. The final task is analysis, which involves calculation of functional capacity indices.

Development Phase

The Development Phase of the HGM Approach is ideally carried out by an interdisciplinary Assessment Team, or “A-Team.” The product of the Development Phase is a Regional Guidebook for assessing the functions of a specific regional wetland subclass. In developing a Regional Guidebook, the A-Team will complete the following major tasks. After organization and training, the A-Team must:

a. Classify the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the Hydrogeomorphic Classification (Brinson 1993; Smith et al. 1995).

b. Develop an ecological characterization or functional profile of the subclass, focusing on the specific regional wetland subclass selected.

c. Identify the important wetland functions, conceptualize assessment models, identify model variables to represent the characteristics and processes that influence each function, and define metrics for quantifying model variables.

d. Identify reference wetlands to represent the range of variability exhibited by the regional subclass.

e. Collect field data from the reference wetlands and use to calibrate model variables and verify the conceptual assessment models.

f. Develop the assessment protocols necessary for regulators, managers, consultants, and other end users to apply the indices to the assessment of wetland functions.

The following list provides the detailed steps involved in the general sequence described previously.

Task 1: Organize the A-Team
- A. Identify A-Team members
- B. Train A-Team in the HGM approach

Task 2: Select and Characterize Regional Wetland Subclass
- A. Identify/prioritize regional wetland subclasses
- B. Select regional wetland subclass and define reference domain
- C. Initiate literature review
- D. Develop preliminary characterization of regional wetland subclass
- E. Identify and define wetland functions

Task 3: Select Model Variables and Metrics and Construct Conceptual Assessment Models
- A. Review existing assessment models
- B. Identify model variables and metrics
- C. Define initial relationship between model variables and functional capacity
- D. Construct conceptual assessment models for deriving functional capacity indices (FCI)
- E. Complete Precalibrated Draft Regional Guidebook (PDRG)

Task 4: Conduct Peer Review of Precalibrated Draft Regional Guidebook
- A. Distribute PDRG to peer reviewers
- B. Conduct interdisciplinary, interagency workshop to PDRG
- C. Revise PDRG to reflect peer review recommendations
- D. Distribute revised PDRG to peer reviewers for comments
- E. Incorporate final comments from peer reviewers on revisions into the PDRG

Task 5: Identify and Collect Data from Reference Wetlands
- A. Identify reference wetland field sites
- B. Collect data from reference wetland field sites
- C. Analyze reference wetland data

Task 6: Calibrate and Field Test Assessment Models
- A. Calibrate model variables using reference wetland data
- B. Verify and validate (optional) assessment models
- C. Field test assessment models for repeatability and accuracy
- D. Revise PDRG based on calibration, verification, validation (optional), and fieldtesting results into a Calibrated Draft Regional Guidebook (CDRG).

Task 7: Conduct Peer Review and Field Test of Calibrated Draft Regional Guidebook
- A. Distribute CDRG to peer reviewers
- B. Field test CDRG

C. Revise CDRG to reflect peer review and field test recommendations
D. Distribute CDRG to peer reviewers for final comment on revisions
E. Incorporate peer reviewers' final comments on revisions
F. Publish Operational Draft Regional Guidebook (ODRG)

Task 8: Technology Transfer
A. Train end users in the use of the ODRG
B. Provide continuing technical assistance to end users of the ODRG

Application Phase

The Application Phase of the HGM Approach involves two steps:

a. The first step is to assemble data from existing databases (e.g., maps, hydrologic data, soil survey data), and the collection of site specific field data. These data are then analyzed to develop site specific assessment of current wetlands function.
b. The second step is to apply the results of the assessment (the Functional Capacity Indices) to a review sequence. This may include alternatives analysis, impact minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives, determination of restoration potential, or identification of potential mitigation sites.

3 Regional Wetland Subclass and Reference Domain

This Regional Guidebook was developed to assess the functions of ponded, herbaceous marshes on the loess plain of south-central Nebraska. These wetlands are known locally as Rainwater Basins, or simply Rainbasins. The region is named for its formerly abundant natural marshes that formed where clay-bottomed depressions catch and hold rain and runoff water. The Rainwater Basin wetland region includes all or parts of 17 counties in south-central Nebraska covering roughly 10,880 km^2 (Rundquist 1990). Recoded National Wetland Inventory data from Raines et al. (1990) indicate that approximately 13,812 ha of palustrine emergent wetlands are included in this subclass. These wetlands are dominated by herbaceous hydrophytes, persistent throughout most of the growing season. The three most common Cowardin et al. (1979) water regimes characterizing this subclass are: (a) temporarily flooded, (b) seasonally flooded, and (c) semi-permanently flooded.

The reference domain selected to represent this regional wetland subclass is indicated in Figure 1. Under ideal circumstances, the reference domain selected to develop a Regional Guidebook will mirror the full geographic extent of the regional subclass. However, it is not always possible to garner the time and resources necessary to identify, and sample, the full extent of a regional subclass. For example, reference wetlands for this guidebook were sampled in only the Rainwater Basin geographic area; however, numerous depressional wetlands that have similar formation and potential function to this regional subclass exist in the Todd Valley wetland district (LaGrange 1997) in east-central Nebraska.

Description of the Regional Subclass

Physiography and geology

The Rainwater Basin wetland region is in the High Plains Section of the Great Plains Province (Fenneman 1931). It is in Major Land Resource Area 75, the Central Loess Plains (U.S. Department of Agriculture-Soil Conservation Service (USDA-SCS) 1981). The general physiography of the area is nearly level to gently undulating loess plains with numerous closed basins. The few streams that do dissect the area are very narrow and have little terrace development, except along the Little Blue River. The Rainwater Basin wetland region has sometimes been separated by wetland managers into subregions

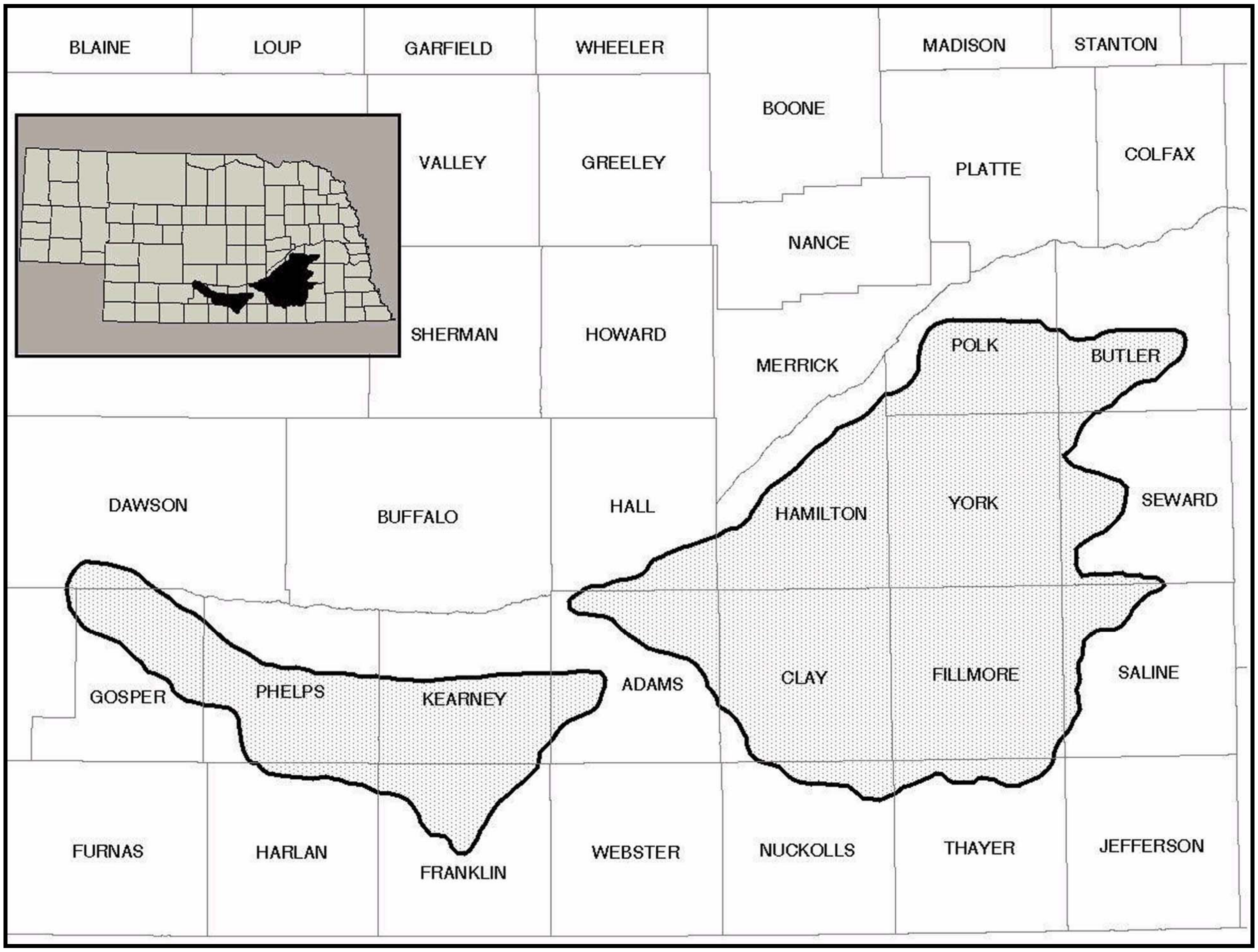


Figure 1. Rainwater Basin reference domain

having a western and eastern component. The eastern component is in the Central Loess Plains Section ecoregion; the western area is in the South-Central Great Plains Section (Bailey et al. 1994).

The High Plains (Fenneman 1931) are remnants of a smooth fluviatile plain that stretches from the Rocky Mountains into eastern Nebraska. The alluvial fills are of Pleistocene age but are not materials from the Midwestern ice sheet. The fills are believed to be a series of coalescing alluvial fans of Rocky Mountain origin which have filled the preexisting valleys and smoothed the landscape. The topography has been further smoothed by the deposition of wind-blown silts (loess) over the silty and gravelly fluviatile materials. The stratigraphy of this area generally consists of various ages of loess deposited over fluvial gravel valley fills. The general sequence of materials in increasing geologic time is Bignell loess, Peoria loess, Loveland formation, Gilman Canyon formation, Roxana loess, Red Cloud/Grand Island fluvial gravels, and bedrock (Dreeszen 1970).

The Rainwater Basin wetland region is an area with poorly developed natural surface drainage resulting in numerous closed basins in which drainage is internal. The numerous surficial depressions are underlain by clayey soils. The fine textured soils impede the infiltration of water, therefore creating numerous ponded wetlands. The origin of the depressional topography has been the subject of conjecture for many years. Early speculation was that the numerous small depressions on the Great Plains were the result of deflation (i.e., wind erosion) during drier climatic episodes, animal activity, or uneven settling of the surface (Gilbert 1895; Frye 1950), possibly because of the action of groundwater (Fenneman 1931). Starks (1984) found that the surface area and volume of the larger Rainwater Basin depressions are linked statistically to the size of the crescent-shaped ridges (lunettes) that occur on the south and east sides of many of the basins. Based upon the occurrence of the lunettes and the lack of soluble bedrock in the area, the most accepted hypothesis on the larger basin's formation is deflation by wind and enlargement by wind and end-current processes (Krueger 1986). Most likely, the depressional wetlands in the area have formed from a variety of processes. The smaller "pothole" depressions (Kuzila 1984) are irregular in shape, range from about 0.1 to 30 ha in size, and are generally less than 1 m below the surrounding land at their lowest point. These depressions do not exhibit any orientation and most likely are formed as the result of wind, animal activity, and/or differential compaction. The larger basins are oval or elongate in shape and range from about 30 to 1,000 ha in size. The floors of the basins are about 2 to 5 m below the surrounding landscape. Most of the larger basins have associated lunettes and likely formed in the manner described by Krueger (1986). Most of the smaller wetlands have been destroyed by agricultural activities such as filling, land leveling, drainage, and sedimentation.

Another geomorphic factor remains unexplained: the orientation and clustering of the wetland complexes within the region. The elongation of individual basins can be explained by wind and end-current processes, the concentration and elongation of clusters of wetlands (Starks 1984) cannot be explained thusly. Stratigraphic cross sections have shown that the basins exist on a preexisting depressional topography (Krueger 1986; Kuzila and Lewis 1993). It is possible that the Pleistocene fluviatile deposits did not fully smooth the preexisting erosional topography and that the loess deposits may have blocked paleo-drainageways. These phenomena have caused lake and wetland formation in the Sand Hills of Nebraska (Loope and Swinehart 1992).

Climate

In the Rainwater Basin region, winters are cold because of incursions of cold, continental air that bring frequent spells of low temperature. Summers are hot with occasional interruptions of cooler air from the north. Snowfall is frequent in winter, but snow cover is usually not continuous. Rainfall is heaviest late in spring and early in summer. The spring rains contribute to filling the Rainwater Basin wetlands; however, in years with winter or spring drought many of the basins are dry. Total average annual precipitation ranges from about 460 mm in the western part of the region to 710 mm in the eastern part. About 80 percent of the annual precipitation falls in April through September. Variability in precipitation during the growing season and between years is common. In 2 years out of 10, the rainfall in April through September is less than 330 mm in the west, and less than 430 mm in the east. The Rainwater Basin region is in an area where evapotranspiration generally exceeds precipitation. Therefore, many of the wetlands become dry every year unless they are maintained by artificial water sources (e.g. groundwater wells, irrigation runoff).

Hydrology

The interaction of climate, basin and catchment relationships, and site-specific characteristics affect the magnitude, frequency, and duration of water moving into the basins. The wetlands function as a dynamic system responsive to climatic shifts. Long-term temperature, precipitation regime, and other climatic factors influence the rate at which water is delivered to the wetlands. Catchment characteristics, such as soil type, slope, and land use affect how water and sediment move into the wetlands. Wetland basins are generally circular or oval in shape (some smaller basins are irregular in shape) and range in size from less than 1 to more than 500 ha (Farrar 1996). Because most of the wetlands in the Rainwater Basin are surface water depressions (Novitski 1979), the size of the catchment has a direct bearing upon the size and hydrologic regime of the wetlands.

Similar to other depressional wetlands in the high plains, the dominant hydrologic inputs are precipitation and runoff from surrounding uplands. The hydrodynamics are vertical fluctuations resulting from inundation and evapotranspiration. Wetlands in this regional subclass pond irregularly subject to wide variations in intra- and inter-annual hydrological inputs. This is in response to regional climatic trends. It is common for depressional wetlands on the Great Plains to be dry for several years and then pond for several consecutive years.

Basin characteristics, such as shape, size, and depth affect the retention of water in the wetlands. Most accumulated water is lost by evapotranspiration, but some may leach through underlying materials and produce chemical precipitates that result in a relatively impermeable layer below the land surface. The regional water table is generally 18 to 30 m below the bottom of most of these basins (Keech and Dreezen 1959, 1968), in the upper part of the sand and gravel fluviatile Grand Island formation (Lugn and Wenzel 1938; Keech and Dreezen 1959). Because of the depth to the aquifer, the wetlands generally are considered isolated from groundwater. However, it may be possible that some water seeps downward at the edge of the basins during extreme wet climatic cycles. In the western part of the region, a few wetlands have been impacted by irrigation seepage groundwater (Ekstein and Hygnstrom 1996) and some of the larger waterfowl management areas are artificially supplemented by groundwater pumping.

Soils

Soils in reference wetlands of the Rainwater Basin depressional subclass are very deep, poorly to very poorly drained, and medium to fine textured. The soils have formed in the Peoria and Bignell loess. Generally, they have a silt loam surface, and silty clay or clay subsoils. These soils occur on 0- to 1-percent slopes, have very slow permeability, and runoff is ponded. The very slowly permeable clayey subsoil creates a perched water table from 0.6 m above (i.e., ponded) to 0.3 m below the soil surface. The soil series form a continuum based upon the moisture gradient; therefore, morphological differences in some of these soils are not always apparent. It appears the soils were mapped in concentric rings around the basins based upon an interpretation of ponding duration.

The deepest parts of the wetter depressions are the Massie soil, which is very poorly drained and ponded for much of the growing season. It generally corresponds to the semi-permanently (Cowardin et al. 1979) inundated water regime. The next drier soil in the sequence is the Scott series. It is poorly to very poorly drained and has a semi-permanently to seasonally inundated water regime. The driest soil in the sequence is the Fillmore soil. It is poorly drained and has a temporarily inundated water regime. The Fillmore soils have a leached E horizon above a clayey argillic horizon (i.e., claypan) which has formed as a result of ferrolysis or eluviation (Fanning and Fanning 1989). The formation of the E horizon in these soils has also been attributed to sedimentation of silty material from the surrounding landscape (Kuzila 1988). It is possible that the genesis of the Fillmore soil mapped around the larger basins is a result of sedimentation and not ferrolysis or eluviation. Another soil type commonly associated with the depressional landscape setting is the Butler silt loam, generally considered transitional between the previously discussed hydric and upland soil series. This deep, nearly level, somewhat poorly drained claypan soil is found mostly on flat or slightly concave areas of uplands. A few areas are in slightly concave positions on stream terraces. Small inclusions of Fillmore soils can be found within this soil map unit.

The soils of the surrounding landscapes are formed in silty loess and generally have silt loam to silty clay loam textures. These soils are susceptible to erosion by water, especially when used for row crops or during heavy spring thunderstorms.

Vegetation Communities

The geographic extent of the Rainwater Basin region generally corresponds to the mixed grass prairie (western region) and tall grass prairie (eastern region) described by Kaul (1975) in his cartographic description of the potential natural vegetation of Nebraska. Extensive work by Weaver and Bruner (1954) documented the presence of these regional associations and the drought induced movement of mixed prairie eastward on a regional scale. From this evaluation, they documented a regional ecotone at the 98° 30' west longitude. This longitude roughly bisects the Rainwater Basin region as described by the Nebraska Game and Parks Commission (1972). Specific to the wetland subclass of interest, Weaver and Bruner (1954) noted the “depressed areas” on the loess plain, the affinity of wetland vegetation with the depressional clayplan areas (Fillmore and Scott soil series), and qualitatively described vegetation composition based on depth and permanence of water. Other qualitative observations of wetland vegetation were provided by Witt (1979) for wetland management needs. Again, representative species were assigned to describe different zones based on water depth and permanence.

Quantitative phytosociological investigations are limited to that of Erickson and Leslie (1987) and Gilbert (1989). For the former study, weighted average ordination stand scores describing plant community wetness were evaluated relative to depressional soil series for eight study sites. A more extensive regional survey was conducted by Gilbert (1989). This study provided descriptive information on vegetation/soils relationship and documented species composition for 47 study sites. Soils and vegetation mapping data as well as preliminary evaluation of vegetation response to wet-dry cycles were also provided. A listing of dominant or descriptive species by general zones and Cowardin et al. (1979) wetland classes is provided in Table 5.

Table 5
Generalized Vegetation Zones for Rainwater Basin Depressions as Adapted from Weaver and Bruner (1954) and Gilbert (1989). (Nomenclature has been updated to reflect the Great Plains Flora Association (1986))

Wetland Class (Cowardin et al. 1979)	Zone Description	Dominant or Common species	Common Name
PEMF[1]	Water more or less continuously deep	*Scirpus* spp. *Typha* spp.	Bulrush Cattail
PEMF/PABF[2]	Flooding stage, persistent in shallow water or drawdown	*Potamogeton* spp. *Marsilea vestita* *Bacopa rotundifolia* *Heteranthera peduncularis* *Alisma subcordatum* *Eleocharis acicularis* *Lemna* spp.	Pondweed Pepperwort Water hyssop Mud plantain Water plantain Needle spikesedge Duckweed
PEMF/PEMC[3]	Shallow water emersed water plants	*Eleocharis palustris* *Polygonum amphibium* *Polygonum bicorne* *Coreopsis tinctoria* *Sagittaria* spp.	Spikerush Water smartweed Pink smartweed Plains coreopsis Arrowhead
PEMC/PEMA[4]	Outer edges of larger depressions, or scattered irregularly through shallower depressions	*Echinochloa* spp. *Hordeum jubatum* *Phalaris arundinacea* *Ammannia coccinea* *Cyperus acuminatus* *Vernonia fasiculata* *Lippa cuneifolia* *Gratiola neglecta* *Ambrosia tomentosa* *Polygonum pennsylvanicum* *Eleocharis* spp. *Carex* spp. *Rumex crispus*	Barnyard grass Foxtail barley Reed canarygrass Tooth-cup Tapeleaf flatsedge Ironweed Wedgeleaf fog-fruit Hedge hyssop Perennial bursage Smartweed Spikerush Sedges Curly dock
PEMA/UPLAND[5]	Border of depressions	*Agropyron smithii* *Buchloe dactyloides* *Bouteloua gracilis* *Carex* spp. *Apocynum* spp.	Western wheatgrass Buffalo-grass Blue grama Sedges Dogbane

[1] Palustrine emergent semi-permanently flooded wetland.
[2] Palustrine aquatic bed semi-permanently flooded wetland.
[3] Palustrine emergent seasonally flooded wetland.
[4] Palustrine emergent temporarily flooded wetland.
[5] Upland areas outside this zone are generally cool season grasses, planted warm season grasses, or agricultural lands.

Factors influencing species composition and distribution in prairie depressional wetlands include hydrologic regime, salinity of water, the edaphic complex, plant competition, pH, nutrient status, and the seed bank response to wet/dry cycles (Dix and Smeins 1967; Walker and Coupland 1968; Dirshl and Coupland 1972; Stewart and Kantrud 1972; Miller 1973; van der Valk and Davis 1978a, b; van der Valk 1989; Middelton 1999). Walker and Wehrhahn (1971) stated that disturbance is the major environmental gradient affecting species distributions. Cultivation was considered as the most drastic type of disturbance by Walker and Coupland (1968) and considered to "override" the effects of other natural gradients. All of the above factors may be influencing Rainwater Basin plant communities. For the majority of these wetlands, alterations of the hydrologic regime through drainage and land use practices are probably the principal factors determining floristic composition.

Fauna

Over 257 species of birds have been recorded in the Rainwater Basin. However, Rainwater Basin wetlands are most noted for their importance to waterfowl, especially during the spring migration (Gersib et al. 1992; Gersib et al. 1990; U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). These wetlands are host to five to seven million spring-migrating ducks and geese annually, providing loafing and feeding areas necessary for building up nutrient reserves for continuation of migration to northern breeding grounds. Approximately 90 percent of the midcontinent population of greater white-fronted geese, 50 percent of the midcontinent population of mallards, and 30 percent of the continental population of northern pintails utilize the Basins during spring migration. In wetter years, substantial numbers of ducks are produced (Evans and Wolf 1967). Wetland habitat loss has resulted in waterfowl overcrowding during the spring migration. Consequently, there is an increased potential of disease outbreaks (Smith and Higgins 1990). Avian cholera (*Pasteurella multocida)* has been a chronic problem in the region since the late 1970s (Stutheit 1988).

The Rainwater Basin wetlands also provide important fall migration habitat for endangered species, shorebirds, wading birds, and other bird species. Forty-two percent of confirmed whooping crane (endangered) observations in Nebraska have been at the Rainwater Basin wetlands. Since 1942, when whooping cranes were recorded in the Rainwater Basin, these wetlands have provided more whooping crane use-days during fall migration than any other known migration habitat in the United States' portion of the Central Flyway. Surveys have identified that roughly 200,000 to 300,000 shorebirds represented by over 30 different species migrate through the basins. Other species include; bald eagle, great blue and black-crowned night-herons, gulls, sandhill cranes, white-faced ibis, and bitterns. Many of these wading species utilize the basins for foraging, loafing and nesting. They often forage in shallow waters searching for aquatic insects, amphibians, snails, and crustaceans. Cattail stands provide ample nesting areas for species such as the red-winged blackbird and bitterns. Many other nongame birds, including Neotropical migrants, also make use of these basins.

Resident species also depend on the Rainwater Basin wetlands. Raccoon, whitetail deer, pheasant, rabbit and amphibians to name a few, depend on the basins for water, food, and cover. Many of these resident species feed in cropped areas nearby but then use the dense marsh areas for cover.

Cultural Alteration of Wetland Basins and the Landscape

The Rainwater Basin wetland region of south-central Nebraska is one of the most endangered wetland systems in North America (Smith 2001a, b). The most common cultural alterations in the Rainwater Basin region that affect this regional wetland subclass are related to agriculture. It has been estimated that prior to European settlement in the mid 1800's there were approximately 3,900 major Rainwater Basin wetlands, covering an area of approximately 38,000 ha (Gersib et al. 1992). It is likely that many more small basins existed on the landscape; however, it is impossible to quantify their historic extent. The Nebraska Game and Parks Commission (1984) estimated that less than 10 percent of the original basins and 22 percent of the original wetland acres remained as compared to early soil surveys.

More recent estimates of basin numbers and remaining area are based on National Wetland Inventory (NWI) data and modern soil surveys. An interagency team using recoded NWI data documented 13,812 ha remaining (Raines et al. 1990). Smith and Higgins (1990), in their study of avian cholera relative to wetland densities, documented 445 wetlands remaining in the region, comprising 11,436 ha. Also noted in their study was that 81 percent of the 445 wetlands remaining were affected by drainage. Whatever the figures, historic losses are high, and the remaining wetlands provide fragmented habitat in an intensely cultivated landscape. Rainwater Basin wetlands have been identified by the U.S. Fish and Wildlife Service as one of the nine areas in the U.S. of critical concern for wetland losses (Tiner 1984). The Rainwater Basins were designated a "waterfowl habitat area of major concern" in the North American Waterfowl Management Plan (USFWS and CWS 1986). This led to the establishment of the Rainwater Basin Joint Venture in 1992 (Gersib et al. 1992).

In addition to the total destruction of wetlands resulting from drainage and/or filling, almost all of the remaining wetlands have been directly impacted by agriculture and/or road building. The construction of irrigation water reuse pits (i.e., dugouts, concentration pits) is a common practice. The excavations diminish wetland functions by shrinking productive littoral zones and concentrating water. Other direct impacts to the wetlands include sedimentation by topsoil eroding from the adjacent uplands and excess nutrients and pesticides being carried into the wetlands with the sediment via runoff. Like much of the agricultural Midwest, roads in the region have been built on nearly every section line. These roads fragment many wetlands and their ditches often transport water out of the wetlands or act similar to concentration pits and hold water.

Not only have the wetlands themselves been altered, but also their associated catchments have been modified. Some wetlands receive additional water from irrigation runoff or road ditches. Because most of the original prairie has been converted to cropland, timing and amounts of runoff have been altered. In addition, roads, catchment diversion structures, regional ditch networks, and other landscape alterations all affect the natural functions and hydrology of the area's wetlands.

4 Wetland Functions and Assessment Models

Overview

The following functions performed by Rainwater Basin wetlands in Nebraska were selected for model development:

a. Water Storage

b. Cycle Nutrients

c. Remove, Convert, and Sequester Elements, Compounds, and Particulates

d. Maintain Habitat for Characteristic Plant Community

e. Provide Wildlife Habitat

A landscape scale function has also been developed and is documented in Appendix B, section entitled "Summary of Functions for Rainwater Basin Depressional Wetlands." This function was developed specifically for use by waterfowl management agencies.

Reference Data Collection

General

A total of 32 reference sites, either partial wetland assessment areas or full wetland assessment areas, were evaluated. The model variables selected for describing Rainwater Basin functions were derived from data collection involving characterization of elevation, vegetation, soils, and hydrology at each study site. Site characterization field data were collected in July and August for both 1996 and 1997. Additional information for site characterization and the relationship of the reference sites to the surrounding landscape were based upon project specific color-infrared photography flown in the fall of 1996 at a scale of 1 in. = 660 ft or 201 m, analysis of elevation data from corresponding U.S. Geological Survey 7.5-min quadrangles, and U.S. Geological Survey digital orthophotos. The characterization of each site complex, was evaluated from

National Wetland Inventory data. Locations of reference sites are provided in Appendix C, Table C1.

Site characterization

Upon arrival at each assessment area, a primary transect was established to intersect observed vegetation zones. Transect endpoints extended through the hydric soil boundary to surrounding uplands. At selected sites, a secondary transect line was established perpendicular to the main axis when needed. Soils and vegetation data were collected at intervals along the main and secondary transect line. Vegetation sample locations along the transect were selected to characterize species' composition and abundance within each zone. A modified Daubenmire (1968) canopy coverage scale was used. Soil profile descriptions were conducted at almost all vegetation sampling locations, additional soil profiles were evaluated at the discretion of the soil scientist of the project. Topographic data and documentation of the features of a site were collected using a theodolite. Benchmarks were established in relation to permanent features observed on aerial photography. These locations were assigned coordinates from complementary GPS surveys. Theodolite data were subsequently converted to latitude/longitude coordinates. Attributes collected consisted of edge of the hydric soils, plant community boundaries, road ditches, culverts, transect endpoints, maximum wetland depth, and locations of vegetation/soils samples. From project aerial photography, cover maps of each reference site were prepared. Classification was based on the Cowardin et al. (1979) system.

Catchment characterization

Catchment boundaries for each site were determined from elevational data from U.S. Geological Survey 7.5-min topographic maps, county soil surveys, and field reconnaissance. Cartographic renditions of the historic and present day catchments were subsequently developed. Additionally, area of land use/land cover for each present day catchment was documented.

Landscape characterization

Digital National Wetland Inventory data were used to describe the reference sites' relationship to the surrounding wetland complex. Inter-wetland distance and area of wetlands within in an artificially defined complex were described.

All the preceding data were integrated into geographic information system coverages and thematic databases. The following variables represent the results of reference data collection and served in the description of the functions chosen:

- Vegetation and habitat
  - $V_{grasscont}$ - Continuity of Grassland Around the Wetland
  - $V_{grasswidth}$ - Width of Grassland Around the Wetland
  - $V_{vegcomp}$ - Vegetation Composition of the Wetland

- Soils
    - V_{sed} - Sediment Deposition in the Wetland
    - V_{pore} - Soil Pores and Structure
- Hydrologic
    - V_{mod} - Wetland Modifications
    - V_{out} - Wetland Outlet
    - V_{source} - Reduction or Increase in Catchment Area
- Landscape and land use
    - $V_{wetarea}$ - Wetland Density in the Landscape
    - $V_{wetprox}$ - Proximity to Nearest Wetlands
    - V_{wetuse} - Land Use Within the Wetland
    - V_{upuse} - Land Use Within the Catchment

In the next section of this chapter, each variable is discussed in terms of the metrics' relationship to the subindex score. After presentation of this information, models for each of the designated functions will be presented.

Model Variables

Vegetation and habitat variables

Grassland Continuity ($V_{grasscont}$). This variable represents the average continuity of grassland around the perimeter of the wetland. Grassland continuity (Figure 2) is measured by determining the perimeter (meters) of the

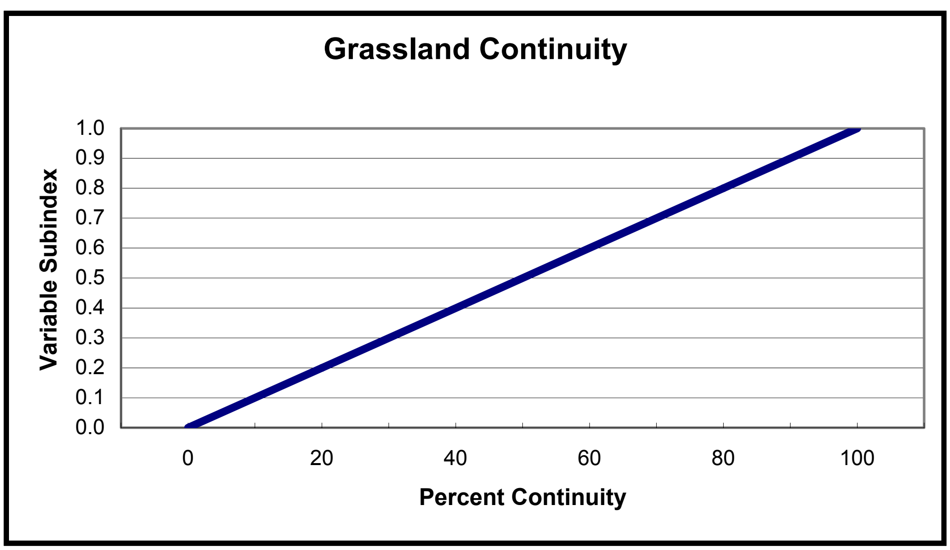


Figure 2. Relationship between grassland continuity and the variable subindex score

wetland boundary that is contiguous with grassland. This measure is then divided by the total perimeter of the Wetland Assessment Area (WAA) and is expressed as a percent for calculation of the variable subindex score. Based on the range of values at reference sites, a score of 0 indicates that no grassland was contiguous with the wetland edge and a score of 1.0 indicates the entire wetland perimeter was surrounded by grassland. For n = 32, mean value was 44 percent. The scores for the reference sites ranged from 0 to 100 percent.

Grassland Width ($V_{grasswidth}$). This variable represents the average width in meters of grassland adjacent to the wetland edge. Grassland width (Figure 3) is measured from the wetland perimeter to an area buffered to a 30-m distance. The width of grassland is measured at 12 equidistant intervals of the perimeter and an average width determined. A score of 0 indicates that there is no grassland surrounding the wetland within the buffered distance from the wetland edge. A variable subindex score of 1.0 is assigned when the entire buffered perimeter is composed of grassland. For n = 32, the index scores ranged from 0 to 28 m. Mean value was 12 m. Although none of the reference sites met the 1.0 subindex score, it is known that there are wetlands in the Rainwater Basin that would achieve a 1.0 subindex score.

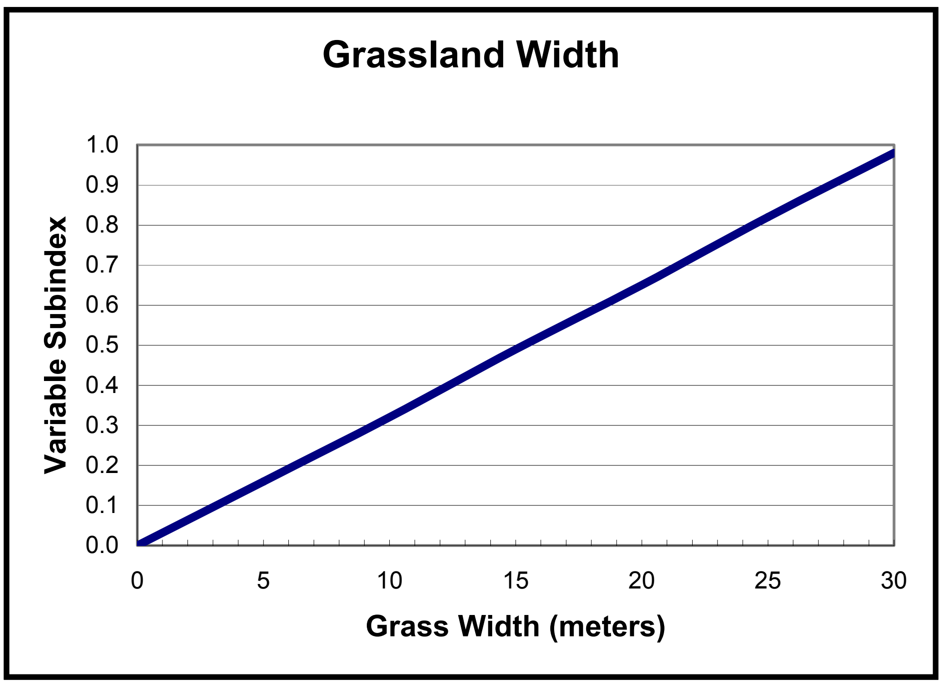


Figure 3. Relationship of grassland width to the variable subindex

Vegetation Composition ($V_{vegcomp}$). This variable represents the floristic quality of a wetland as determined from the dominant vegetation. The dominant vegetation of each plant community within a wetland is assumed to indicate overall native species richness and diversity.

Each dominant species is assigned an indicator value based upon floristic quality assessment procedures in Taft et al. (1997). This involves assignment of a Coefficient of Conservatism (termed *C* value) to species records. *C* values range from 1 to 10, with 0 being taxa associated with severely disturbed areas and generally consisting of invaders; and *C* values of 10 being taxa associated with natural areas.

General descriptions of *C* value categories are as follows:

- 0-1: Taxa that are adapted to severe disturbance, particularly anthropogenic.
- 2-3: Taxa that are associated with more stable, though degraded habitat.
- 4-6: Taxa that have a high consistency of occurrence within a given community type and will include many dominant or matrix species for several habitats.
- 7-8: Taxa that are associated predominately with natural areas but can persist where the habitat has been somewhat degraded.
- 9-10: Taxa that exhibit a high degree of fidelity to a narrow range of synecological parameters.

C values were assigned to all species records from the reference data set and those records from Gilbert (1989). Assignments were after Rolfsmeier and Steinauer (2003), with modification. Species records and *C* value assignments can be found in Appendix C, Table C3. Modifications are noted and relate to only woody species which were considered "invasive species" for this herbaceous, depressional subclass. From the Coefficient of Conservatism assignment, dominant species were further categorized based upon information in the following tabulation:

Indicator Category (dominant species only)	Abbreviation	Floristic Quality Indicator Criteria
Reference Standard species	RSS	C-value $\geq$3
Native non -invasive species	NN	C-value <3
Exotic/Invasive species	EI	Nonnatives, Invasive natives

A weighted average percent concurrence with reference standard and other native dominant species (excluding invasive) is determined for each plant community within the wetland. This index is then multiplied by the percent area for each plant community. The sum of those scores provides an overall site score for this variable.

$$V_{vegcomp}: \sum ((\#RSS_i + 0.5(\#NN_i)) / n_{ij}) * Percent\ area_j \qquad (1)$$

where:

$V_{vegcomp}$ = Sum of the weighted scores for each plant community *j* in the wetland assessment area

$\#RSS_i$ = Number of reference standard dominant species in the plant community

$\#NN_i$ = Number of native dominant species in the plant community

$\#RSS_i + 0.5(\#NN)_i$ = Weighted percent concurrence in the plant community

n_{ij} = Total number of dominant species in the plant community $_j$

Percent area $_j$ = Relative area of the plant community $_j$

The site scores ranged from 0 to 100 percent concurrence for the reference sites (Figure 4). Mean value for all reference sites (n = 32) was 67 percent. A subindex score of 0 indicates dominance in all zones by invasive native or exotic species. A value of 1 indicates dominance of reference standard dominant species in all zones. The relationship of the site score to the subindex is assumed to be linear.

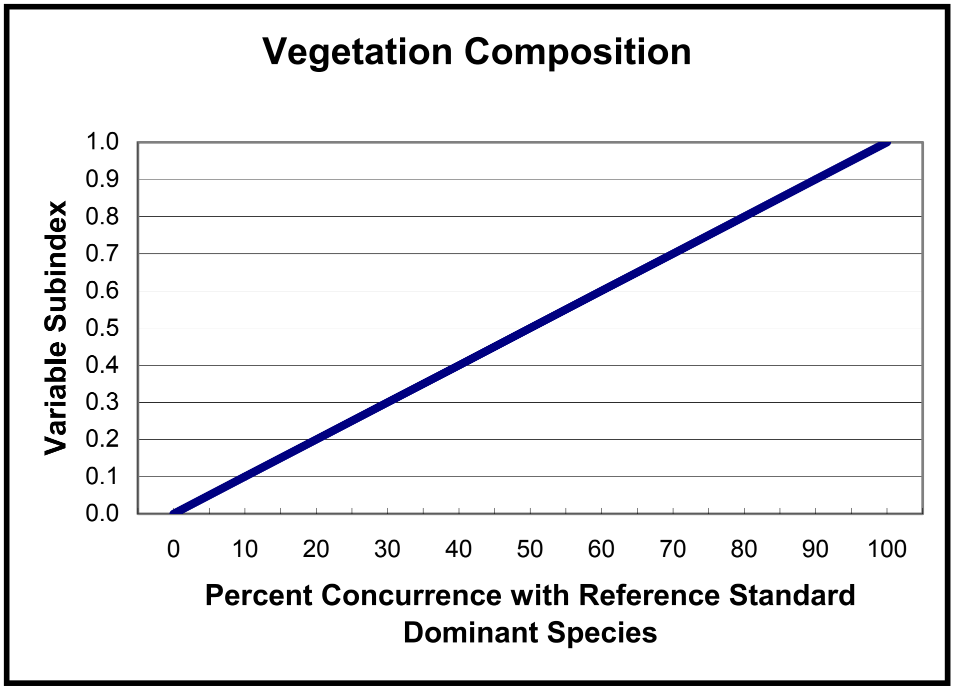


Figure 4. Relationship of the concurrence of dominant species with the variable subindex

Soil variables

Sediment (V_{sed}). This variable is defined as the extent of sedimentation within the outer depressional soil or vegetative zone (usually the Fillmore soil or the temporary zone) from culturally accelerated sources. Also evaluated under this variable is fill material used for land leveling or spoil disposal. V_{sed} is measured by determining the depth to the *Bt* for replicate, averaged sample pedons within the outer depressional soils. *Bt* depths for the reference sites ranged from 7.0 to 50.0 cm. A variable subindex score of 1.0 was assigned when the depth to the *Bt* occurred between the interval of 25 to 33 cm. Based on data from reference wetland sites, this interval was assumed to be in the range of natural variation for Rainwater Basin wetlands and reflects the reference standard condition. As depth to the Bt decreases, a linearly decreasing subindex down to zero is assigned. This would be indicative of the condition of soil removal.

Similarly, increases in *Bt* depth beyond the 33-cm depth were assumed to be from culturally accelerated erosion rates from within the catchment or deposition of fill (Figure 5). Therefore, subindex scores are assumed to decrease inversely from this point.

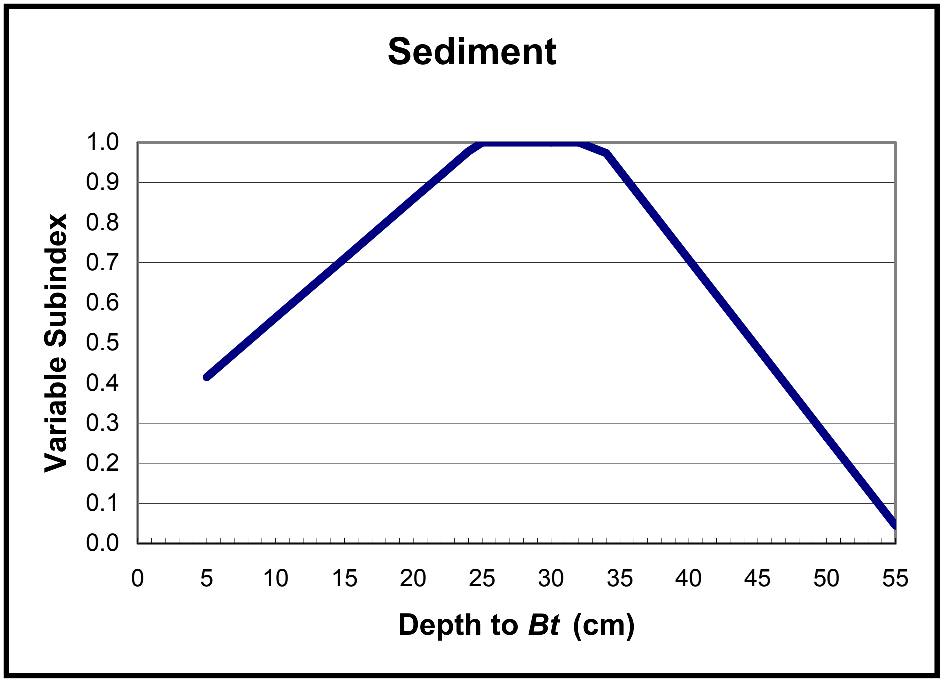


Figure 5. Relationship of the depth to *Bt* and the variable subindex

Soil Pores and Structure (V_{pore}). This variable represents the physical integrity of the soil surface layer (A or Ap horizon) within the outer depressional soil. This variable is measured by determining the grade, size, and continuity of nonmatrix pores and coarse clods. Evaluation of these soil attributes correlate to the presence or absence of a plow pan and relative degrees of soil disturbance. Numbers assigned for each characteristic are listed in Table 6.

The summation of these values for a pedon description are then used to determine the Physical Soil Quality Index (PSQI). Data are averaged across replicates within the outer depressional zone. This unitless measurement assesses anthropogenic impacts to near-surface soil physical properties that reflect soil porosity and the ability of the soil to allow infiltration and movement of water. Water moving into and through the soil is important for improving existing moisture conditions, maintaining plant growth, preventing erosion, and maintaining soil water storage capability. The possible range for the PSQI is a minimum of 6 and a maximum of 25 (Figure 6). Actual data range for reference data was was 9 to 23. The higher the number, the better the physical integrity of the soil. A variable subindex score of 1.0 was assigned for PSQI values of ≥23.

Table 6 Soil Characteristics Evaluated in Determination of the Physical Soil Quality Index				
Characteristic	**Value**			
	0	**1**	**2**	**3**
Ap		Present	Absent	
Pores		Few	Common	Many
Pore Continuity		Low	Moderate	High
Compound Structure		No	Yes	
Structure Grade	Massive	Weak	Moderate	Strong
Structure Size	Massive	Coarse or Thick	Medium	Fine or Thin
Structure Shape	Massive	Platy	Subangular Blocky	Granular
Consistence		Firm	Friable	Very Friable
Roots		Few	Common	Many

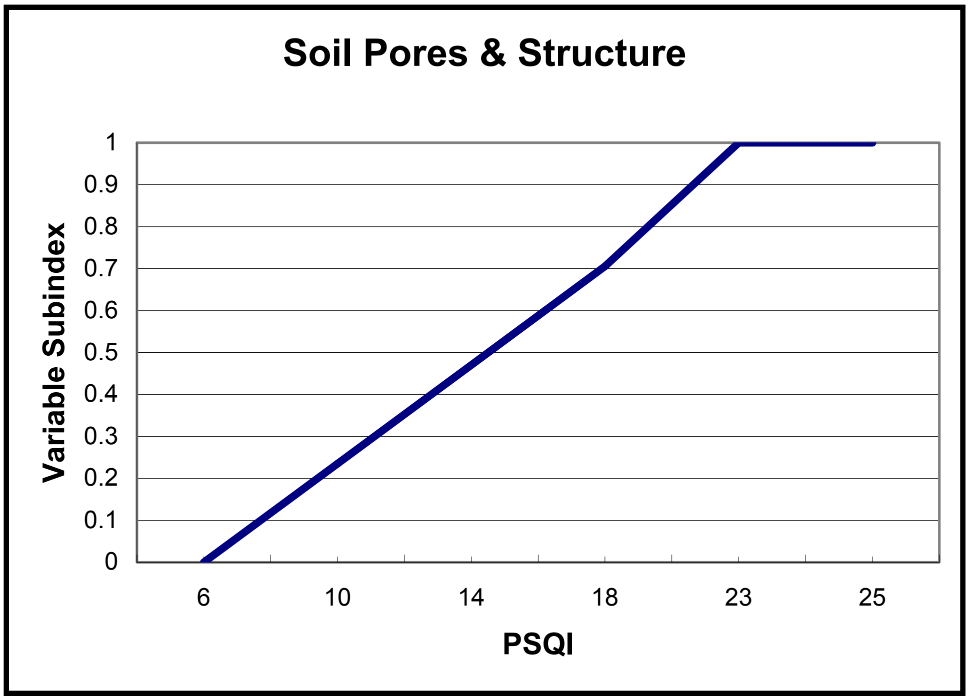


Figure 6. Relationship of soil quality with the variable subindex

Hydrologic variables

Wetland Modifications (V_{mod}). Wetland modifications are the presence or absence of constructed features such as dikes or fill for physical structures such as roads, berms, building pads, etc. within the wetland (fill material used for land leveling or spoil disposal is evaluated under V_{sed}), or the input or removal of water from the wetland as a result of irrigation. The direct effects of wetland modifications on hydrology as defined are difficult to measure and therefore this variable is scored qualitatively.

Dikes, including roads, generally cause a redistribution of water within the wetland rather than a removal. Irrigation runoff into a wetland can cause an increase in hydrology making the area wetter than it was historically. This can cause a temporary wetland to take on the nature of a seasonal, or even semi-permanent wetland. Conversely, use of an irrigation pump to remove water from a wetland usually ensures that the area remains dry and eliminates the possibility of a pit overfilling and flooding the wetland. The descriptive conditions provided in Table 7 should be used to scale this variable.

Table 7
V_{mod} Categorical Variable

Measurement or Condition - V_{mod}	**Subindex Score**
Condition A - Natural conditions present, no dikes or fill within the wetland that restrict or redirect flow or change the wetland water regime class, no pumping or irrigation tailwater additions -OR- wetland has been fully restored.	1.00
Condition B - Dike or fill bisects the wetland area and the amount of isolated wetland is proportional to the amount of the isolated catchment area -OR- dike has an unrestricted culvert(s) with the invert at or below natural grade.	0.85
Condition C - Dike(s) with water control capability keep water on a wetland and does not change the wetland water regime class -OR- increased flows to the wetland supplement or correct altered hydrology.	0.60
Condition D - Dike(s) or fill bisect wetland and change the wetland water regime class -OR- land leveling has resulted in a land use modification with marginal success -OR- groundwater presence has altered the natural wetland water regime class and soil characteristics -OR- sediment/soil ridge ponds shallow water outside of the wetland.	0.30
Condition E - Dike(s) or artificial pumping keep the wetland dry -OR- land leveling or fill has raised the elevation of the bottom of the wetland above the temporary zone.	0.0

Wetland Outlet (V_{out}). This variable is a measurement of features, both natural and anthropogenic, which remove water from the historic wetland. It is measured within the hydric soil footprint and requires depth measurements within the wetland assessment area. Features such as drainage ditches, tile lines, deep road ditches, reuse or concentration pits within the hydric soil footprint, and alteration of natural outlets or overflows are all included in the definition of wetland outlet (Figure 7).

These alterations can occur singly or in various combinations and may have a significant effect on wetland hydrology. Alterations that extend only into the temporary zone of a seasonal or semipermanent wetland often allow some wetland to remain. Those that are situated or extend into the deepest portion of the wetland generally drain the entire area.

Measurements are based on a continuous scale, requiring calculation of the percent of the historical wetland volume that is now held in excavations where:

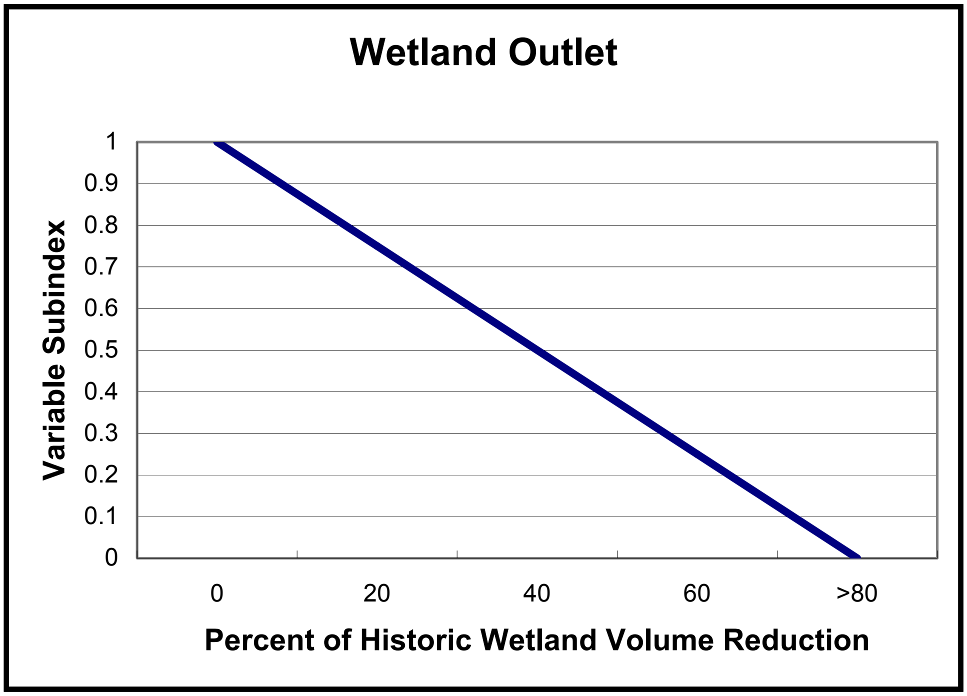


Figure 7. Relationship of volume reduction to the variable subindex

$$V_{out} = (\text{volume of excavations(s) / volume of historic wetland} \times 100) \quad (2)$$

Or based categorically on the appropriate description of wetland condition as indicated in Table 8. Using the continuous or categorical portrayal of this variable is at the option of the user in consideration of application needs.

Table 8
V_{out} Categorical Variable

Measurement or Condition - Vout	Subindex Score
Natural conditions present, no physical alteration(s) or excavations within the wetland -OR- no physical alteration of the natural outlet elevation -OR- no change to the wetland water regime class or size because of alterations -OR- wetland has been fully restored.	1.00
Invert of constructed outlet is within the temporary zone and above the lowest elevation in the wetland, and current wetland size is less than historic and no pumping occurs except during irrigation season.	0.75
Invert of constructed outlet is above the lowest elevation in the wetland with a full-capacity ditch -OR- undersized tile surface inlet is present within the wetland or full sized with restricted outlet and no pumping occurs except during irrigation season.	0.50
Invert of constructed outlet is at the lowest elevation of the wetland and is a full-capacity ditch or full-sized tile surface inlet with functional outlet and no pumping occurs except during irrigation season.	0.10
Constructed outlet at or below the lowest elevation of the wetland, wetland completely drained -OR- constructed pit with pumping completely drains the wetland.	0.00

Variable subindex scores for the continuous measurements ranged from 0 to 165 percent. For $n = 31$, mean value was 18 percent. A variable subindex score of 1.0 was applied when there is no volume held in excavated features. When >80 percent of the wetland's potential volume was held in excavated features, a subindex of 0 was assigned as it was assumed that significant change in the characteristic water regime had occurred.

Source Area of Flow (V_{source}). This variable is a measure of the percent change, either an increase, decrease, or combination of both, in the catchment area surrounding a wetland. Alterations in the catchment have a direct effect on the amount of water flowing off the landscape into the wetland. In some instances where land leveling for irrigation has occurred, an actual increase in catchment size has resulted. More commonly, the placement of reuse pits, county roads, and other alterations within the catchment have intercepted or diverted flows from wetlands. In some catchments, it is not unusual to have both an **increase** to the catchment along with a **decrease** because of a combination of the various alterations. By using soil survey maps, aerial photos, and topographic maps, the original or historic catchment boundary can be delineated with relative accuracy. Then, additions or reductions to the catchment are determined to find the percent change which has occurred. Subindex values are scored as either continuous scale, by dividing the present day catchment by the historical catchment, or categorically, based on the appropriate description of catchment condition as indicated below (Table 9). For the reference wetlands' catchments, percent change of the contributing area ranged from approximately a 60-percent reduction to an increase of 168 percent. In this latter case and other sites exceeding 100 percent, the contributing catchment area has been increased because of anthropogenic influences. Based on the range of values at reference standard sites, a variable subindex of 1.0 is assigned when percent change of the catchment is between 90 and 110 percent (Figure 8). Below 90 percent, the subindex decreases linearly to the condition where surficial water flow is effectively eliminated. Above the 110-percent interval, the subindex also decreases inversely. This is based on the assumption that additions of water through altered flow paths or irrigation inflows will alter the characteristic water regime. *Using the continuous or categorical portrayal of this variable is at the option of the user in consideration of application needs.*

Table 9
V_{source} Categorical Variable

Measurement or Condition - V_{source}	Index
Minimal alteration of the upland catchment source area through structural surface alterations or irrigation additions.	1.00
Surface alterations of the upland catchment source area which impact overland flow into the wetland have occurred, however, no irrigation additions -OR- the maximum density (# per square mile) of standard size tail-water recovery pits within the catchment is < 1.4/square mile.	0.75
Surface alterations of the upland catchment source area are changed to alter the dominant surface flow path of water to the wetland. However, the alteration(s) does not change the wetland water regime class -OR- the maximum density of standard size tail-water recovery pits within the catchment is 1.5 to 4.4/square mile.	0.50

(Continued)

Table 9 (Concluded)	
Measurement or Condition - V_{source}	**Index**
Surface alterations of the upland catchment source area is changed to alter the dominant surface flow path of water to the wetland and the alteration changes the wetland water regime class (e.g. a seasonal wetland has been changed to a semi-permanent) -OR- the maximum density of standard size tail-water recovery pits within the catchment is 4.5 to 7/square mile.	0.10
The upland catchment source area is extremely altered such that almost all water flow to the wetland is eliminated -OR- the maximum density of standard size tail-water recovery pits within the catchment is >7/square mile.	0.00

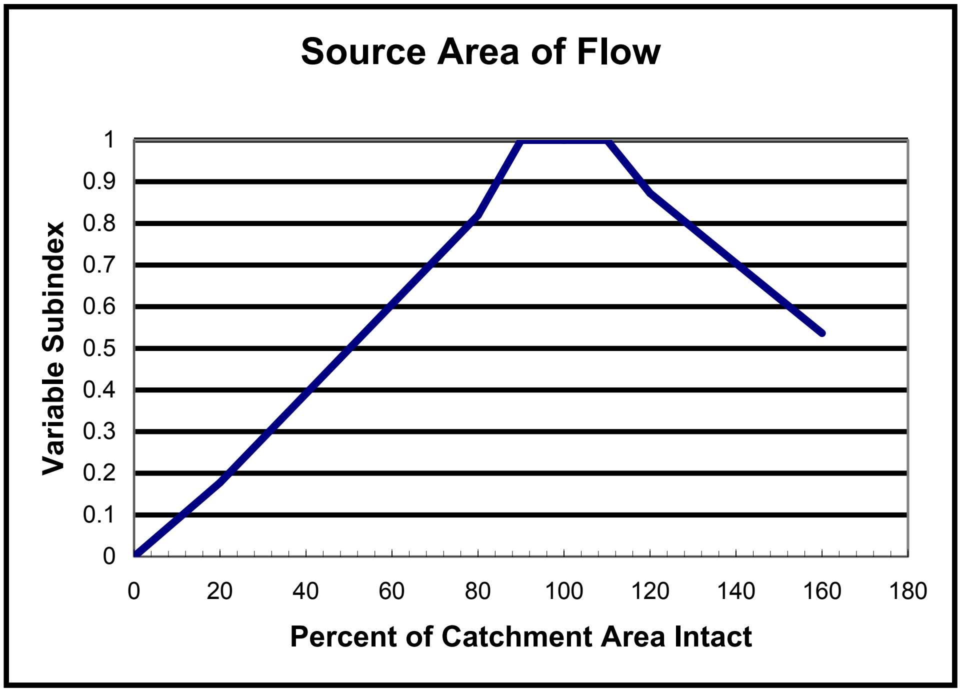
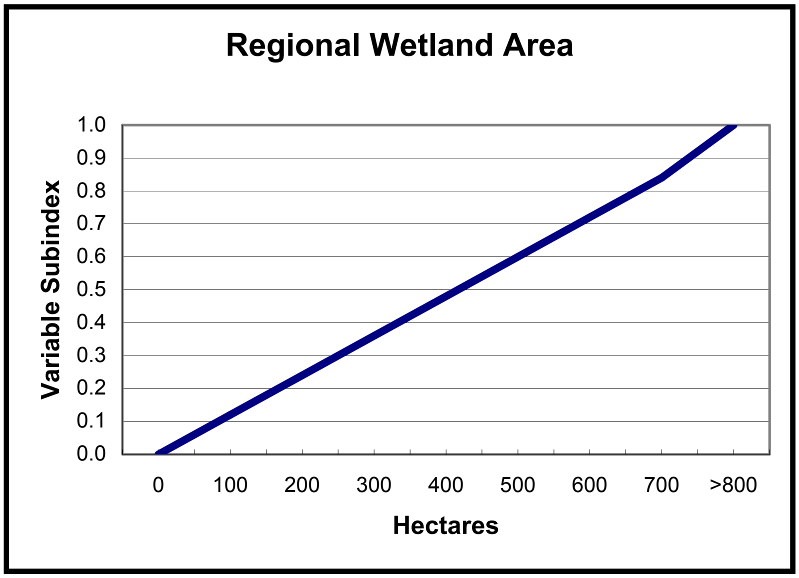


Figure 8. Relationship of the existing catchment to the variable subindex

Landscape and land use variables

Regional Wetland Area ($V_{wetarea}$). This variable is a measure of the area of palustrine wetlands (hectares) occurring within a 4.83-km radius (3 miles) from the assessment wetland. It is used as a measure of the condition of the wetland complex associated with the assessment wetland at the landscape scale. Area measurements ranged from approximately 46 to 814 ha. Mean area for the reference sites' complex (n = 32) was 254 ha. The relationship of the metric to the variable subindex score is assumed to be a linear relationship (Figure 9).

Figure 9. Relationship of the wetland area to the variable subindex



Nearest Wetland Neighbor ($V_{wetprox}$). This variable is a measure of the mean interwetland distance from the assessment wetland to the nearest five wetlands. Units are in meters (m). It is also used as an indicator of the wetland complex condition, with emphasis at a finer scale of resolution as compared to the $V_{wetarea}$ variable. Interwetland distance metrics ranged from approximately 51 to 1,600 m. Mean value for reference sites (n = 31) was 537 m. The relationship of the metric to the variable subindex score is assumed to be an inverse linear relationship (Figure 10).

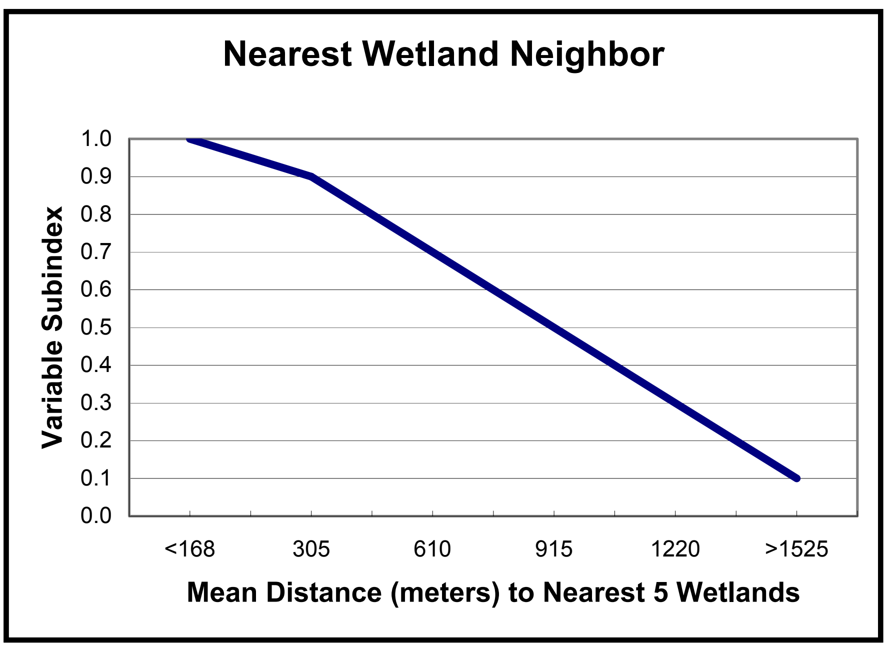


Figure 10. Relationship of wetland proximity to the variable subindex

Wetland Land Use (V_{wetuse}). This variable represents the condition of the wetland based upon observed land uses. It is assessed for the entire hydric soil footprint of the wetland assessment area. V_{wetuse} is measured by determining the area by specific categories of land use and applying a weight for each land use category. A weighted average unitless "site score" is then calculated. The weights applied for land use categories were based upon concurrence of the A-Team. A weight of 1 indicates the highest degree of anthropogenic disturbance to the wetland while a weight of 10 would approximate the reference standard. The remaining weights applied to each land use category represent relative intensities of anthropogenic disturbance (Table10).

Table 10
Land use weights for calculation of V_{wetuse}

Current Land Use	Weight
Fill - Creating upland within the wetland	0
Deep Water - Deep enough to preclude other land uses	1
Annually Cropped	3
Perennial Cover - Undisturbed	4
Occasionally Cropped	5
Perennial Cover - Heavily Grazed	6
Perennial Cover	8
Perennial Cover - Prescribed Management for High Diversity Plant and Animal Communities	10

Wetland areas that had land uses that simulated more natural occurrences, such as moderately grazed or hayed, received a higher score than areas that were undisturbed. Idle, though sometimes used as a wetland management practice, actually does not simulate historic conditions and was categorized accordingly. For n = 30, the scores for the reference sites ranged from 3.0 to 8.6. Mean value was 5.4. A weighted average of 10.0 was not achieved but is known to occur within the reference domain. Values >8.6 were assigned a variable subindex score of 1.0 (Figure 11).

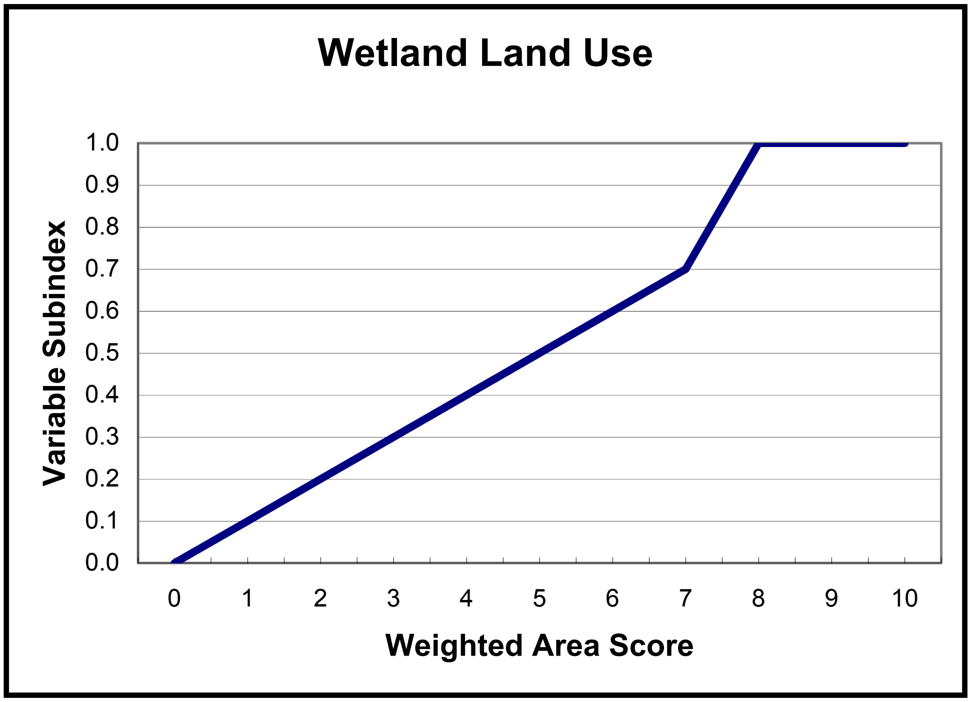


Figure 11. Relationship of the wetland land use with the variable subindex

Upland Land Use (V_{upuse}). This variable represents the condition of the terrestrial cover within the present-day catchment of the wetland being assessed. It is measured by determining the area of land use within various categories and developing a unitless weighted average score. The weights applied for land use categories were based upon concurrence of the A-Team. Weights of 1 indicate the highest severity of impacts to the catchment, while a weight of 10 would approximate the reference standard, least disturbed catchment. Similar to Vwetuse, each remaining land use category represents relative intensities of anthropogenic disturbance. Weights for land use categories are provided in Table 11.

Table 11
Land use weights applied to calculation of V_{upuse}

Current Land Use	Weight
Urban/Road	1
Feed Lot	1
Row Crop	3
Small Grain	4
Farmstead	6
Woodlot/Shelterbelt	6
Perennial Cover	10

Based on data from reference wetlands, a variable subindex score of 1.0 is assigned for a weighted average score of 10. Values for the reference sites ranged from 3 to 10. Mean value was 4.7 for $n = 29$. The relationship of the metric to the variable subindex score is assumed to be a linear relationship (Figure 12).

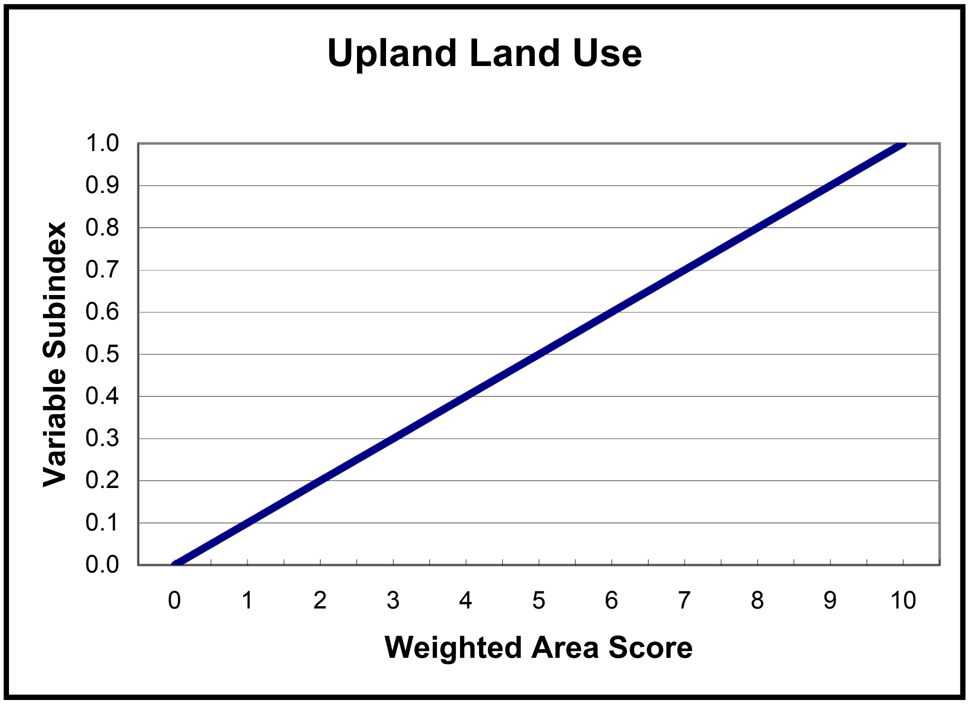


Figure 12. Relationship of the upland land use with the variable subindex

Rainwater Basin Wetland Functions

The following sequence is used in articulation of the selected functions.

a. *Definition:* Defines the function and identifies an independent quantitative measure that can be used to validate the functional index.

b. *Rationale for selecting the function:* Provides the rationale for why a function was selected and discusses onsite and offsite effects that may occur as a result of lost functional capacity.

c. *Characteristics and processes that influence the function:* Describes the characteristics and processes of the wetland and the surrounding landscape that influence the function.

d. *Functional capacity index:* Describes the assessment model from which the functional capacity index is derived and discusses how model variables interact to influence functional capacity.

Function 1: Water Storage

Definition. The function "Water Storage" is defined as the capacity of depressional Rainwater Basin wetlands to store water, primarily under the influence of precipitation or snow-melt within the catchment. Storage is normally lost to evapotranspiration or to seepage into the substrate when the pool extends beyond the outer boundary of the hydric soils. Short-term (dynamic) storage alters the amount of runoff from the landscape into streams. Long-term (static) storage adds moisture to the soil's unsaturated zone, has a significant effect on biogeochemical cycling, and in particular has a very strong effect on floral and faunal populations. A potential independent, quantitative measure for validating the functional index is use of the statistical five-way model for change in volume developed during analysis of hydrology data. Regression analysis of hydrology data for the set of reference wetlands explained 67 percent of the variation in change in volume. These actual measures were transformed to indicators of function (variables) in the model for user ease. Another potential independent quantitative measure of this function would be the amount of water stored in the wetland per a given time (e.g., hectare-meters/year).

Rationale for selecting the function. This function is critical to the maintenance of the wetland and is often considered as the main forcing function for all other wetland processes. Water storage in Rainwater Basin wetlands is important for three reasons. First, storage of surface water alters the amount of runoff into streams thereby ensuring a decrease in flood crests downstream. Second, it guarantees that sufficient moisture is available to allow the development and maintenance of hydric soils and appropriate hydrophytic plant communities. The presence of these plant communities ensures wildlife habitat is available for a variety of species, both resident and migratory. And finally, water storage supports the biogeochemical processes that occur in wetlands such as the removal of nutrients and particulates. This process results in improved water quality.

Characteristics and processes that influence the function. Wetlands are transitional between terrestrial and open-water aquatic ecosystems. They are transitional in terms of spatial arrangement as well as the amount of water they store and process. Wetlands represent the aquatic edge of many terrestrial (emergent) and aquatic (submersed) plants and animals. Thus, small changes in hydrology can result in significant biotic changes (Mitsch and Gosselink 1993). Modifications to the physiochemical environment of a wetland can have a direct impact on the biotic response in the wetland (Gosselink and Turner 1978). When hydrologic conditions in wetlands change even slightly, the biota may respond with massive changes in species composition and richness and in ecosystem productivity. On the other hand, when hydrologic patterns remain similar from year to year, the wetlands structural and functional integrity may persist for many years (Mitsch and Gosselink 1993).

The features and processes that influence the capacity of Rainwater Basin depressional wetlands to store water are both natural and anthropogenic (human-induced) in origin. Climate, catchment characteristics, landscape-scale geomorphic characteristics, and qualities of the soils and vegetation within and around the wetland are factors established by natural processes. In general, the intensity, duration, and areal extent of precipitation events affect the magnitude of the storm-flow response. Typically, the higher the intensity, the longer the duration, and the greater the areal extent of a rainfall event, the greater the runoff volume becomes. Catchment characteristics such as size, shape, and slope can also have a pronounced effect (Brooks et al. 1991; Dunne and Leopold 1978; Ritter, Kochel, and Miller 1995; Patton 1988). Larger catchments contribute greater volumes and peaks in runoff as will catchments with steep slopes. Round-shaped catchments concentrate runoff more quickly and tend to have higher peak flows than elongated ones. The geomorphic origin of Rainwater Basin wetlands is the result of wind deflation, animal activity, and uneven settling of the surface. These various geomorphic processes greatly affected parent soil characteristics, flow pathways, and even feasibility of different land uses.

Anthropogenic alterations also influence the ability of Rainwater Basin wetlands to store water. Drainage to gain additional farm ground, land leveling for gravity flow irrigation, and placement of irrigation reuse pits both in the wetland and the upland catchment have been the primary hydrologic impacts to wetlands. The county road system with road placement around each section has also had a major impact on many wetlands. Another important influence is accelerated sedimentation from soils washed into the basins from the surrounding crop fields. Various combinations of these alterations have affected the ability of many wetlands to retain surface water and thus they can lose their wetland characteristics.

Generally, Rainwater Basin wetlands are the fullest in March, April, and May. Summer precipitation usually is unable to fully augment evapotranspiration losses during the dry months of July, August, and September. Rainwater Basins are perched wetlands not naturally connected to groundwater. Therefore, the water budget is predominately controlled by precipitation and runoff from adjacent uplands. However, some western basins in Phelps and Kearney counties are now supplemented by artificial groundwater inputs resulting from groundwater mounding occurring in the vicinity of the tri-county irrigation canal. These wetlands have become predominately semi-permanent in nature.

The characteristics associated with the performance of this function focus on land use as it impacts volume and timing of water entering the wetland, the volume of the wetland available for storage, the condition of the soils and plants (evapotranspiration, seepage, and soil storage), and activities that reduce retention time (e.g., artificial drainage). Activities above or within the wetland affect the rate and quantity of surface and subsurface water entering and leaving the wetland. Land use activities also affect erosion up-slope and sediment import into the wetlands. An increased sediment load will decrease the wetland’s capacity to store water, sometimes nearly eliminating storage capacity (Luo et al. 1997). Finally, the elevation and capacity of the outlet below the static storage boundary directly impacts the height of the water level and, therefore, the ability of the depression to capture and retain water.

Although accumulation and retention of sediments and particulates is a recognized function of depressional wetlands resulting in improved water quality, it has a negative effect on wetland hydrology. Rainwater Basin wetlands are closed basins, thus sediment inputs are derived primarily from wind and water erosion of upland soils within the catchment. Upland land use affects the movement of water, sediment, and pollutants into the wetland. Generally, the higher the percentage of catchment under perennial cover, the better the condition of the wetland. Properly managed perennial cover helps to slow the movement of water downslope, which aids in the filtering of sediments and entrapment of pollutants. The chief negative impact to wetlands of accelerated sedimentation is loss of volume because of filling. In the playa wetlands of Texas, Luo et al. (1997) found that basins in cultivated catchments had lost nearly all of their original volume because of filling by sediment. Precipitation that was once lost through evapotranspiration or infiltration to groundwater before entering wetlands with grassland catchments enters via spates of surface runoff from tilled catchments. The accelerated runoff often brings erosional sediments from the surrounding landscape contributing to filling the basin with soil. In addition to the alteration of hydrologic inputs, the loss of basin volume from siltation reduces the water storage capacity and flood attenuation benefits of wetlands (Brun et al. 1981; Ludden et al. 1983).

Functional Capacity Index. The assessment model for calculating the FCI for the function "Water Storage" is as follows:

$$FCI = \sqrt{V_{out} \times \sqrt{\sqrt{V_{mod} \times V_{source}} \times \frac{\left(V_{sed} + V_{upuse} + V_{pore}\right)}{3}}} \qquad (3)$$

In the model, the variable having the greatest impact on the ability of a wetland to perform this function is wetland outlet. Alterations that perform year round to remove water from the wetland have a major impact on hydrology. Simply stated, if the wetland has been so hydrologically modified that it is completely drained (subindex = 0), then the wetland no longer has the capacity to perform the function "Water Storage" and the FCI equals zero. The variables sediment, upland land use, and soil pores and structure in combination can also have impacts on this function, but each by itself are less important than the other variables.

Function 2: Cycle Nutrients

Definition. The function "Cycle Nutrients" reflects the ability of an individual Rainwater Basin depressional wetland to convert nutrients from inorganic forms and back, through a variety of biogeochemical processes such as respiration, photosynthesis, reduction, and oxidation. Potential independent quantitative measures for validating the functional index include standing stock of living and dead biomass (gm/m^2), net annual primary productivity (gm/m^2), annual accumulation of organic matter (gm/m^2), and annual decomposition of organic matter (gm/m^2).

Rationale for selecting the function. The cycling of nutrients (including nonessential elements) is a fundamental process performed by all ecosystems, but the cycling tends to be accomplished at particularly high rates in many wetland systems (Mitsch and Gosselink 1993). It allows wetlands to maintain an adequate supply of nutrients throughout the abiotic (nonliving) and biotic (living) components or variables of the Rainwater Basin ecosystem. The use of the term cycling refers to the annual turnover or release of nutrients. The biotic components of nutrient cycling comprise the uptake of nutrients by plants to develop and maintain plant growth and then the renewed uptake of nutrients from decayed plants. Abiotic components involve the reduction and oxidation of elements and compounds. It is an important function because it allows wetlands to maintain a relatively high level of net primary production and allows characteristic plant communities to develop and flourish. In performing this function, wetlands can maintain sufficient nutrients to support living biomass and detrital stocks within the wetland. In turn, the living and decaying biomass provide habitat structure and energy for animals and microorganisms. Without this cycling of nutrients, wetland ecosystems would become depleted of nutrients and primary production, secondary production, and decomposition processes would decrease thereby altering ecosystem structure. The recycling of nutrients in the wetland ecosystem may do more to maintain a favorable biogeochemistry (i.e., good water quality) than relatively permanent removal of inflowing nutrients by the wetland. While the foregoing sentence may overstate the case in a few wetlands, imagine the capacity of a wetland to remove nutrients that had neither annual net primary productivity (ANPP) nor detrital turnover. Further, without the return of nutrients from detritus, ecosystems would quickly become depleted of nutrients and their primary production would decrease. In short, the function is responsible for maintenance of living biomass and detrital stocks. Many of the processes involved in nutrient cycling have been extensively studied in wetlands (Brinson et al. 1981).

Characteristics and processes that influence the function. The variables for this function represent biotic and abiotic components of the Rainwater Basin ecosystem that are involved in biological and geochemical processes. In wetlands, nutrients are stored within, and cycled between, four major compartments: (a) the soil, (b) primary producers such as vascular and nonvascular plants, (c) consumers such as animals, fungi and bacteria, and (d) organic matter, such as plant litter or woody debris, referred to as detritus. The transformation of nutrients within and between compartments is mediated by a complex web of biogeochemical processes. Nutrient cycling or biogeochemical cycling through plants during the processes of photosynthesis and respiration are the most recognized processes. Oxygen is needed for respiration, and the diffusion of oxygen in water is 10,000 times slower in water than in air. Wetland plants, hydrophytes, are unique in that they have adapted to living in water or wet soil environments. Physiological adaptations in leaves, stems, and roots allow for greater gas exchange and permit respiration to take place and allow the plant to harvest the stored chemical energy it has produced through photosynthesis. Although there is no clear starting or ending points for nutrient cycling, it can be argued that it is the presence of water in the wetland that determines the characteristic plant community of hydrophytes. In turn, it is the maintenance of the characteristic primary productivity of the plant community that sets the stage for all subsequent transformations of energy and materials at each trophic level within the wetland. It follows that alterations that change the amount of living and decayed plant matter will directly affect the way in which the wetland can perform this function.

Nutrient cycling can be assessed directly and quantitatively by measuring the rate at which plant biomass is accumulated, turned over (annual litter fall), and decomposed, and analyzing the content of nutrients associated with each process. However, the time and level of effort to accomplish this is well beyond the scope of rapid assessment. Therefore, the level of functional capacity must be assessed indirectly using variables that reflect nutrient cycling in the wetland. Measurements of these characteristics reflect the level of nutrient cycling taking place within a wetland. Comparison of these data, between an assessed wetland and the characteristics of reference standard wetlands, indicate changes in the level of nutrient cycling.

The function can be approached logically. If living and detrital biomass are distributed in the wetland being assessed in the same proportions and quantities as occurs at reference standard sites, it is unlikely that the cycling of nutrients could differ significantly between the two conditions. One way of estimating living and dead biomass is to estimate biomass and cover of the vegetation, and the volume and cover of detritus. Each of these components are related as variables to reference standards and appropriately aggregated into the variables for the index of function. This is the approach used for the wet pine flats case study (Rheinhardt et al. 1997) and the regional guidebook for western Kentucky riverine wetlands (Ainslie et al. 1999).

Functional Capacity Index. The assessment model for calculating the FCI for the function "Cycle Nutrients" is as follows:

$$\mathrm{FCI} = \frac{\left(\dfrac{V_{vegcomp} + V_{wetuse}}{2}\right) + \left(\dfrac{V_{pore} + V_{out}}{2}\right)}{2} \tag{4}$$

In the model, the capacity of a depressional wetland to cycle nutrients depends upon two characteristics. The first is the presence of the characteristic amount of plant biomass represented by the variables vegetation composition and wetland land use. The second characteristic, the presence of the detrital and soil components, is represented by the variables soil pores and structure and wetland outlet. These partially compensatory variables are averaged based on the assumption that all detrital components are given equal importance in nutrient cycling.

The two parts of the model are averaged because production and decomposition processes in nutrient cycling are considered to be interdependent and equally important. Therefore, a characteristic level of nutrient cycling will not be achieved if nutrient cycling processes related to primary production or decomposition are reduced. An arithmetic, rather than geometric mean is used because it may be possible under certain circumstances for some variable subindices to drop to 0.0 for a short time. This would not result in the function being eliminated.

Function 3: Remove, Convert, and Sequester Elements, Compounds, and Particulates

Definition. The function "Remove, Convert, and Sequester Elements, Compounds, and Particulates" reflects the ability of an individual Rainwater Basin depressional wetland to permanently remove or temporarily immobilize elements, compounds (nutrients), and particulates that are imported from upland sources, or occur onsite. Elements include nitrogen, phosphorus, and potassium and compounds include herbicides and pesticides that can be toxic in high amounts. Inorganic and organic particulates are physically immobilized. The term "removal" pertains to the permanent loss of elements and compounds such as in deep burial (retention) or loss to the atmosphere and the term "sequestration" means the short- or long-term immobilization of elements and compounds. A potential independent, quantitative measure of this function is the amount of one or more imported elements and compounds removed or retained per unit area during a specified period of time (e.g., $g/m^2/year$).

Rationale for selecting the function. The functioning of wetlands as interceptors of nonpoint source pollution is well documented (Johnston 1991). Elements and contaminants in surface and groundwater that come in contact with wetland soils and vegetation are either removed over the long term by sedimentation or are transformed into innocuous and biogeochemically inactive forms. There are several reviews on nutrient removal by wetlands, including those of Faulkner and Richardson (1989) and Johnston (1991). From the mid-1970s to the mid-1980s, much research and development effort was invested in utilizing wetlands as sites for tertiary treatment of wastewater (U.S. Environmental Protection Agency (USEPA) 1983; Godfrey et al. 1985; Ewel and Odum 1984). Because of their location on the landscape, depressional wetlands, particularly those in lower portions of catchments, are strategically located to process nutrients and contaminants before they can contribute to groundwater and/or surface water pollution (Crumpton and Baker 1993). Jones et al. (1976) showed that even a slight increase in the percentage of wetlands in an agricultural catchment reduced the amount of nitrate loads of streams leaving the watershed. Studies of natural wetlands receiving cropland runoff have shown a nitrate nitrogen removal rate as high as 90 percent (Baker 1992).

The primary benefit of this function is that the removal, conversion, and sequestration of elements and compounds by depressional wetlands reduces the load of nutrients and pollutants in groundwater and in any surface water leaving the depressional wetland. This translates into better water quality and aquatic habitat downstream and in adjacent wetlands and lakes. Sediment deposition in these depressions has been accelerated from cultural sources, especially agriculture. This has resulted in thicker surface layers especially in the outer depressional soils of wetlands. In some areas, wind erosion or land leveling has resulted in thinner surface and subsurface layers. The soil formation and sedimentation of the depressions of the Rainwater Basin influences the functional removal of elements, compounds, and particulates.

Characteristics and processes that influence the function. There are two categories of characteristics and processes that influence the capacity of a depressional wetland to remove, convert, and sequester elements, compounds, and particles. The first deals with the mechanisms by which the elements and compounds are transported to the wetland, and the second deals with the structural components and biogeochemical processes involved in the function.

The variables of this function reflect land use and the biotic and abiotic components of the Rainwater Basin ecosystem. Land use activities impact the elements and compounds entering the system and the natural removal and retention processes of these elements, compounds, and particulates. The related variables are grassland width, grassland continuity, upland land use, wetland land use, and sediment. Biotic components remove elements and compounds through plant growth and decay. Rates of decomposition are slow enough to sequester or remove nutrients within the wetland. The related variable is vegetation composition. Abiotic components assist the reduction and oxidation processes that biogeochemically sequester elements and compounds. The related variables are wetland outlet, source area of flow, and soil pores and structure.

Functional Capacity Index. The assessment model for the function "Remove, Convert, and Sequester Elements, Compounds, and Particulates" is:

$$FCI = \frac{V_{grasswidth} + V_{grasscont} + V_{out} + V_{source} + V_{upuse} + V_{wetuse} + \left(\frac{V_{pore} + V_{sed}}{2}\right)}{7} \qquad (5)$$

In the conceptual model, the capacity of a depressional wetland to remove, convert, and sequester elements, compounds, and particulates is made up of two parts. The first deals with the mechanisms by which the elements and compounds are transported to and from the wetland and is represented by the variables $V_{grasswidth}$, $V_{grasscont}$, V_{out}, V_{source}, V_{upuse}, and V_{wetuse}. The six variables are equally independent.

The second part deals with the biogeochemical processes involved in the function and is represented by the variables V_{pore} and V_{sed}. The two variables are partially compensatory based on the assumption that they are independent and contribute equally to performance of the function.

The two parts of the model are averaged because the variables are considered to be interdependent and equally important. Therefore, a characteristic level of removing, converting, and sequestering will not be achieved if mechanisms and processes are reduced. An arithmetic, rather than geometric, mean is used because it may be possible under certain circumstances for some variable subindices to drop to 0.0 for a short time. This would not result in the function being eliminated.

Function 4: Maintain Habitat for Characteristic Plant Community

Definition. "Maintain Habitat for Characteristic Plant Community" is the capacity of a Rainwater Basin wetland to possess and sustain the environment necessary for characteristic plant communities to develop and respond to changing environmental conditions including soil condition, hydrology inputs, wetland land use, and land use within the catchment. In assessing this function, one must also consider the extant plant community as a response to previous hydrologic cycles and the synergistic effects of natural and anthropogenic disturbances. A potential independent measure of this function would be direct or indirect ordination methods based on vegetation composition and abundance as well as environmental factors (Gauch 1982; ter Braak 1994).

Rationale for selecting the function. The ability to maintain a characteristic plant community is important because of the intrinsic value of the plant communities and the many attributes and processes of Rainwater Basin wetlands that are influenced by the plant communities. Emergent macrophytes represent the majority of biomass in primary productivity and subsequent loading into nutrient cycling. Macrophytic translocation of nutrients is a major source of internal loading. Litter fall, plant senescence, and the process of decomposition provides release of nutrients for reuse by other aquatic organisms.

In addition to these trophic relationships, emergent vegetation provides a structural component for fauna that depends on wetlands for fulfillment of some or all of their life cycle requirements. Weller (1988) stated that structure rather than taxonomic composition is of greatest importance to nesting avifauna. The structure and composition of the plant communities may also directly or indirectly influence floodwater retention, sediment retention, and surface-groundwater interaction at a local or regional scale.

Characteristics and processes that influence the function. A variety of physical and biological factors determine the ability of a Rainwater Basin wetland to maintain characteristic plant communities. Historically, climate, large ungulate grazing, and fire all significantly influenced Rainwater Basin wetlands and their plant communities. In recent decades, anthropogenic alterations have greatly impacted Rainwater Basin wetlands and their plant communities. Gilbert (1989) stated that alterations of the hydrologic regime through drainage and land use practices are the principal factors determining floristic composition. Mapping data from Raines et al. (1990) indicate that approximately 90 percent of the extant wetlands have classification modifiers describing hydrologic manipulations (partly drained or excavated). Conversion of native prairie to an agricultural landscape has caused movement of topsoil into wetland basins. Sedimentation has been shown to significantly reduce species richness, propagule emergence, and germination of wetland macrophytes (Gleason and Euliss 1998). Increased sedimentation therefore selects for monotypic stands of aggressive native species (e.g., *Typha spp.*) or invasive exotic species (*Phalaris arundinacea*). Development of monotypic stands of emergents may effectively remove some of the variation in decomposer organisms that could act to maintain or increase vegetation heterogeneity (Kantrud 1986). Build up of litter in monotypic stands may also result in slower rates of decomposition (Kantrud et al. 1989). To assess this function, vegetation composition and environmental factors known to influence vegetation establishment and regeneration need to be evaluated. Human disturbances that mimic or simulate natural disturbances are less likely to threaten plant community integrity than are disturbances radically different from the natural regime. For managed systems, the goal is not to eliminate disturbance, but rather to maintain processes within limits or ranges of variation that may be considered natural, historic, or acceptable (Noss 1995).

Functional Capacity Index. The assessment model for calculating the functional capacity index (FCI) is as follows:

$$FCI = \frac{\left[\frac{\left(\frac{V_{upuse} + V_{grasscont} + V_{grasswidth}}{3}\right) + \left(\frac{V_{sed} + V_{out}}{2}\right) + V_{wetuse}}{3}\right] + V_{vegcomp}}{2} \qquad (6)$$

In the model, V_{upuse} indicates the condition of the catchment and this is averaged with $V_{grasscont}$ and $V_{grasswidth}$. This provides an indication of the immediate area surrounding the wetland, which will potentially affect the inputs of sediment, and pollutants. Although V_{upuse}, $V_{grasscont}$, and $V_{grasswidth}$ variables are related, any of these variables are capable of diminishing this function. V_{sed} is then averaged with V_{out}. V_{sed} indicates the amount of sediment that has accumulated within the wetland and V_{out} indicates alteration of wetland area though reduction or expansion. Both of these variables affect seed bank dynamics and zonation within the wetland. Next, V_{wetuse} provides an indication of the manipulation within the wetland. This will help ascertain the degree of disturbance of the wetland. Finally, all indirect variables are averaged with $V_{vegcomp}$. Vegetation is the most direct indication of how similar the plant community is to reference standard conditions, but often operates in response to changing environmental conditions. Therefore, $V_{vegcomp}$ is averaged with all the measures of the environmental factors to develop the overall functional capacity index score.

Function 5: Provide Wildlife Habitat Within the Wetland

Definition. The function "Provide Wildlife Habitat Within the Wetland" reflects the ability of an individual Rainwater Basin wetland to support native wildlife species during some part of their life cycle. The focus of this model is on birds, based on the assumption that, if conditions are appropriate to support the full complement of bird species found in reference standard wetlands, the requirements of other animal groups (e.g., mammals, reptiles, amphibians) will be met. In addition, there is more information available for bird use of the Rainwater Basin than is available for the other animal groups.

Because most prairie wetland animals are highly mobile and their wetland use is often seasonal, direct counts of individuals are not recommended. Instead, this function focuses on examining variables that are less subject to these fluctuations. This function can be independently measured by quantifying wildlife abundance and diversity within the wetland. This would need to be done across seasons because wildlife use of a wetland changes seasonally (e.g., some species of birds are only present during migration while others stay to nest). In addition, wildlife use would need to be assessed across years due to the cyclic nature of Rainwater Basin wetlands. Another independent measure would be Habitat Evaluation Procedures (U.S. Fish and Wildlife Service 1976).

Rationale for selecting the function. Rainwater Basin wetlands are an internationally important resource for migratory water birds, especially for waterfowl during the spring migration (Gersib et al. 1992; Gersib et al. 1990; U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). They host millions of spring-migrating ducks and geese annually, providing the nutrient reserves necessary for migration and reproduction further to the north. Approximately 90 percent of the midcontinent population of greater white-fronted geese, 50 percent of the midcontinent population of mallards, and 30 percent of the continental population of northern pintails use the Basins during spring migration. Recent surveys have identified that a minimum of 200,000 to 300,000 shore-birds represented by over 30 different species migrate through the basins during the spring. Over 257 species of birds have been recorded in the Rainwater Basin. Of these, bird survey records indicate 92 species that are known to breed and rear offspring, with waterfowl alone producing over 10,000 young to flight stage in an average water year. Rainwater Basin wetlands are regularly used by the federally endangered whooping crane and the threatened bald eagle. Forty-two percent of confirmed whooping crane observations in Nebraska have been at Rainwater Basin wetlands. These wetlands have provided more whooping crane use-days during fall migration than any other known migration habitat in the United States' portion of the Central Flyway.

Characteristics and processes that influence the function. Rainwater Basin wetlands are very dynamic systems. An understanding of these dynamics is critical in evaluating a wetland's suitability to provide wildlife habitat. The failure to understand and account for these dynamics when conducting a wetland assessment will lead to an inaccurate estimate of a wetland's ability to provide wildlife habitat functions over the long term.

The use of Rainwater Basin wetlands by wildlife is influenced by a variety of factors that are dynamic both spatially and temporally. Within a wetland, one of the most important factors influencing wildlife use is the structure and composition of the plant community (van der Valk 1989; Weller 1987). The structure of the plant community influences the production of seed and invertebrate foods for wildlife, and cover for hiding, resting, and nesting. Wildlife species diversity is generally highest when the wetland is structurally complex (Weller 1987). In addition, an increase in plant diversity will provide for the habitat needs of a greater diversity of wildlife species. The structure and composition of the plant community is influenced by climatic and disturbance events within the wetland. Some of the primary natural climatic and disturbance events occurring in Rainwater Basin wetlands include flooding, drought, storm events (wind, hail, etc.), temperature extremes (early freezes, warm winters, etc.), grazing, trampling, fire, sedimentation, and scouring by the wind (LaGrange 1997).

Of all of the above factors, the hydrodynamics (frequency, depth, and duration of ponding and/or saturation) within the wetland is one of the driving forces in influencing the composition, distribution, and structure of the wetland vegetation (Kantrud et al. 1989). The hydrodynamics is variable because of precipitation patterns in the Rainwater Basin region that change seasonally and among years.

As a result of the interaction of hydrodynamics and other disturbance events, the vegetation in wetlands in the Great Plains, including the Rainwater Basins, undergoes cyclic changes. Van der Valk and Davis (1978b) summarized these phases as dry marsh, regenerating marsh, lake marsh, and degenerating marsh. Weller and Spatcher (1965) referred to the condition when a wetland is an interspersion of half vegetation and half open water as the hemi-marsh.

Wildlife are well adapted to these dynamics and are equipped with an array of life history adaptations (Mitsch and Gosselink 1993). These adaptations include the ability to survive within the wetland for prolonged periods when the conditions are not favorable. For example, some invertebrates and/or their eggs can survive prolonged periods of drought and quickly respond when conditions again become favorable. Some species of reptiles and amphibians will burrow deep within the mud at the bottom of a wetland and survive there until conditions become favorable. Another adaptation is the ability of some species to disperse over limited distances to seek out more favorable conditions. For example, when conditions deteriorate within a wetland, muskrats and many species of reptiles and amphibians will move overland to seek out wetlands nearby that provide more favorable conditions (Beebee 1996; Errington 1963). A final adaptation strategy is the ability of some species to move over large distances. This adaptation is used primarily by migrating birds that rapidly colonize a wetland when habitat conditions are favorable and seek out other wetlands when conditions become less favorable (Helmers 1992; LaGrange and Dinsmore 1989; Swanson and Duebbert 1989; Bellrose 1980).

Because Rainwater Basin wetlands are so dynamic, it is important when assessing wildlife habitat functions to select variables that are not too sensitive to changes caused by natural climate variation or disturbance events. In addition, as was discussed in Chapter 3, Rainwater Basin wetlands have been greatly altered by human-induced changes that include drainage, alteration of catchments, accelerated sedimentation, suppression of fire, the removal or alteration of natural grazing patterns, and the introduction of exotic species. These alterations have often resulted in a more static system and a subsequent reduction in the diversity and structure of the plant and animal communities in these wetlands.

Functional Capacity Index. The assessment model for calculating the functional capacity index (FCI) is as follows:

$$FCI = \frac{V_{out} + \left\{ \frac{V_{wetuse} + V_{sed} + \left[\frac{V_{vegcomp} + V_{upuse} + \left(\frac{V_{grasswidth} + V_{grasscont}}{2} \right)}{3} \right]}{3} \right\}}{2} \qquad (7)$$

Hydrology was given the greatest weight in the functional equation because the alteration of a wetland's natural hydroperiod will result in the greatest impact to wetland dynamics and associated plant and animal community responses. Next in importance in the equation are the variables V_{wetuse} and V_{sed}. The land use of a wetland is a measure of the presence of natural disturbance dynamics or the simulation of these dynamics through management. Sedimentation has an effect on hydroperiod, and excessive sediment can bury plants, seed banks, and invertebrates (Gleason and Euliss 1998; Luo et al. 1997). Sedimentation also leads to a less diverse wetland bottom topography and this favors the establishment and spread of invasive species such as reed canary grass, cattail, and river bulrush. The final variables in the equation are $V_{vegcomp}$, V_{upuse}, and the combination of $V_{grasswidth}$ and $V_{grasscont}$. The composition of the wetland vegetation, although subject to cyclic changes, has a direct effect on wildlife habitat and can also provide a measure of long-term dynamics. In addition, the land use within the wetland's catchment and presence of grassland around a wetland provides habitat for wildlife and influences the vegetative structure and composition of the wetland.

5 Assessment Protocol

Overview

In previous sections of this Guidebook, we provide: (a) background information on the HGM Approach, (b) wetland variables that are indicators of the level of function, (c) the assessment models (FCIs) consisting of those indicator variables, and (d) information on how those indicators and models are used to describe level of function. This chapter provides the specific protocols that should be followed to conduct a functional assessment of Rainwater Basin depressional wetlands. These protocols are designed for, and will generally be used within the context of, the CWA Section 404 permit review process and for determining minimal effects under the Food Security Act (FSA). They may also be used for other wetland management goals or objectives (e.g., monitoring, evaluation) that require independent measure of ecological function of Rainwater Basin wetlands.

The typical assessment scenario is a comparison of preproject and postproject conditions in the wetland. In practical terms, this translates into an assessment of the functional capacity of the wetland assessment area (WAA) under both preproject and postproject conditions and the subsequent determination of how FCIs have changed as a result of the project. Data for the preproject assessment are collected under existing conditions at the project site, while data for the postproject assessment are normally based on the conditions that are expected to exist following proposed project impacts. A skeptical, conservative, and well-documented approach is required in defining postproject conditions. This recommendation is based on the often-observed lack of similarity between **predicted** or "engineered" postproject conditions and **actual** postproject conditions.

This chapter discusses each of the tasks required to complete an assessment of Rainwater Basin depressional wetlands, including:

a. Defining assessment objectives.

b. Characterizing the project area.

c. Screening for red flags.

d. Defining the Wetland Assessment Area.

e. Collecting field data.

f. Data entry and analysis.

g. Appling results of the assessment.

Define Assessment Objectives

Begin the assessment process by identifying the purpose for conducting the assessment. This can be as simple as stating, "The purpose of this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives could be: (a) compare several wetlands as part of an alternatives analysis, (b) identify specific actions that can be taken to minimize project impacts, (c) document baseline conditions at the wetland site, (d) determine mitigation requirements, (e) determine mitigation success, or (f) determine the effects of a wetland management technique. Frequently, there will be multiple purposes identified for conducting the assessment. Defining the purpose(s) will facilitate communication and understanding between the people involved in conducting the assessment and will make the purpose(s) clear to other interested parties. In addition, it will help to establish the approach that is taken. The specific approach will vary to some degree, depending on whether the project is a Section 404 permit review, an Advanced Identification (ADID), an FSA minimal effects determination, or some other scenario.

Characterize the Project Area

Characterizing the project area involves describing the project area in terms of climate, geomorphic setting, hydrology, vegetation, soils, land use, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands at the project area perform functions. The characterization should be written and should be accompanied by maps and figures that show project area boundaries, jurisdictional wetlands, WAA, proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitat, and other important features.

The following list identifies some information sources that will be useful in characterizing a project area.

a. Aerial photographs or digital ortho-photos covering the wetland and surrounding landscape.

b. Topographic and National Wetland Inventory maps (1:24000 scale) covering the wetland and the surrounding landscape with a minimum 3-mile radius.

c. County Soil Survey.

d. Preceding 5 years of Farm Service Agency aerial compliance slides.

e. Climatic records.

f. Farm Service Agency wetlands determination maps and other jurisdictional delineation documents.

Screen for Red Flags

Red flags are features within, or in the vicinity of, the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 12). Many red flag features, such as those based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Screening for red flag features represents a proactive attempt to determine if the wetlands or other natural resources in and around the project area require special consideration or attention that may preempt or postpone an assessment of wetland function. The assessment of wetland functions may not be necessary if the project is unlikely to occur as a result of a red flag feature. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may be unnecessary since the project may be denied or modified strictly on the impacts to threatened or endangered species or habitat.

Table 12
Red Flag Features and Respective Program/Agency Authority

Red Flag Features	Authority[1]
Native Lands and areas protected under American Indian Religious Freedom Act	A
Hazardous waste sites identified under CERCLA or RCRA	H
Areas protected by a Coastal Zone Management Plan	D
Areas providing Critical Habitat for Species of Special Concern	I
Areas covered under the Farmland Protection Act	K
Floodplains, flood ways, or flood prone areas	J
Areas with structures/artifacts of historic or archeological significance	F
Areas protected under the Land and Water Conservation Fund Act	K
Areas protected by the Marine Protection Research and Sanctuaries Act	D
National wildlife refuges and special management areas	I
Areas identified in the North American Waterfowl Management Plan	I
Areas identified as significant under the Ramsar Treaty	
Areas supporting rare or unique plant communities	
Areas designated as Sole Source Groundwater Aquifers	I
Areas protected by the Safe Drinking Water Act	
City, County, State, and National Parks	F, C, L
Areas supporting threatened or endangered species	B, C, E, G, I
Areas with unique geological features	
Areas protected by the Wild and Scenic Rivers Act	
Areas protected by the Wilderness Act	

1 Program Authority/Agency
A = Bureau of Indian Affairs
B = National Marine Fisheries Service (NMFS)
C = U.S. Fish and Wildlife Service
D = National Park Service (NPS)
E = State Coastal Zone Office
F = State Departments of Natural Resources, Fish and Game, etc.
G = State Historic Preservation Officer (SHPO)
H = State Natural Heritage Offices
I = U.S. Environmental Protection Agency
J = Federal Emergency Management Administration
K = Natural Resource Conservation Service
L = Local Government Agencies

Define the Wetland Assessment Area

The WAA is an area of wetland within a project area that belongs to a single regional wetland subclass and is relatively homogeneous with respect to the site-specific criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage, etc.). In most project areas, there will be just one WAA representing a single regional wetland subclass as illustrated in Figure 13. However, as the size and heterogeneity of the project area increases, it is possible that it will be necessary to define and assess multiple WAAs within a project area.

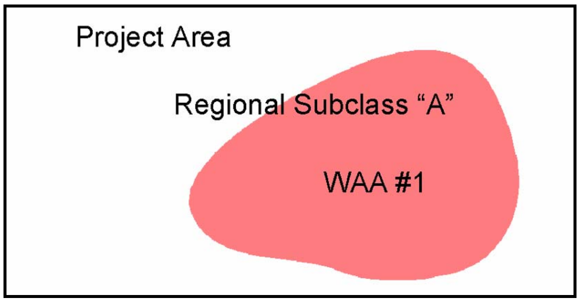
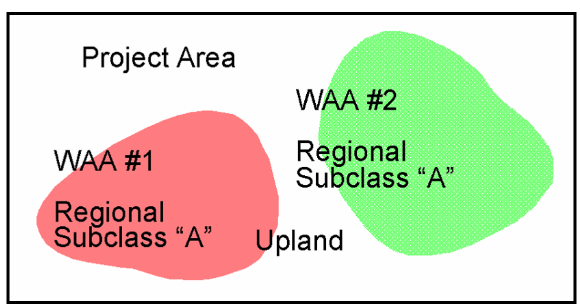


Figure 13. A single WAA within a project area

At least three situations necessitate defining and assessing multiple WAAs within a project area. The first situation exists when widely separated wetland patches of the same regional subclass occur in the project area (Figure 14). The second situation exists when more than one regional wetland subclass occurs within a project area (Figure 15). The third situation exists when a physically contiguous wetland area of the same regional subclass exhibits spatial heterogeneity with respect to hydrology, vegetation, soils, disturbance history, or other factors that translate into a significantly different value for one or more of the site-specific variable measures. These differences may be a result of natural variability or cultural alteration (e.g., farming, urban development, hydrologic alterations) (Figure 16). Designate each of these areas as a separate WAA and conduct a separate assessment on each area.

Figure 14. Spatially separated WAA from the same regional wetland subclass within a project area



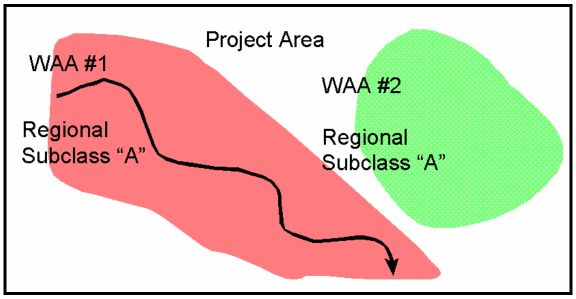


Figure 15. Spatially separated WAA from the same regional wetland subclass within a project area

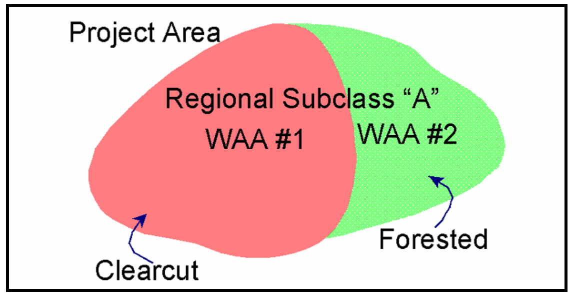


Figure 16. WAA defined based on differences in site-specific characteristics

There are elements of subjectivity and practicality in determining what constitutes a "significant" difference in portions of the WAA. Field experience with the regional wetland subclass under consideration should provide the sense of the range of variability that typically occurs and the "common sense" necessary to make reasonable decisions about defining multiple WAAs. Splitting an area into many WAAs in a project area, based on relatively minor differences, will lead to a rapid increase in sampling and analysis requirements. In general, differences resulting from natural variability should not be used as a basis for dividing a contiguous wetland area into multiple WAAs. However, zonation caused by different hydrologic regimes or disturbances caused by rare and destructive natural events should be used as a basis for defining WAAs.

Collect Field Data

The following equipment is necessary to collect field data.

a. Plant identification keys.

b. Soil probe/sharpshooter shovel.

c. Munsell color book and hydric soil indicator list (U.S. Department of Agriculture, National Resource Conservation Service (NRCS) 1998).

d. 50-m or longer measuring tape, stakes, and flagging.

e. Laser level or other approved surveying equipment.

Information and data about the variables used to assess the functions of Rainwater Basin depressional wetlands are collected at several different spatial scales. Information about landscape scale variables, such as land use, is collected using aerial photographs, maps, and field reconnaissance of the area surrounding the WAA. Subsequently, information about the WAA in general is collected during a walking reconnaissance of the WAA. Finally, detailed site-specific information is collected using sample plots and transects at a number of representative locations throughout the WAA.

The exact number and location of these data collection points are dictated by the size and heterogeneity of the WAA. If the WAA is relatively small (i.e., less than 2 to 3 acres) and homogeneous with respect to the characteristics and processes that influence wetland function, then three or four sample points in representative locations are probably adequate to characterize the WAA. However, as the size and heterogeneity of the WAA increases, more sample plots are required to accurately represent the site.

As in defining the WAA, there is an element of subjectivity and practical limitations in determining the number of sample locations for collecting site-specific data. Experience has shown that the time required to complete an assessment at a several-acre WAA is 2 to 4 hr. Training and experience will reduce the required time to the lower end of this range.

Data and information relating to the 12 variables in this model should be collected according to methods and guidelines provided in Appendix B. Data should be recorded on the field forms also found in Appendix B. Be sure you have collected all on-site data needed in order to avoid a second follow-up site visit.

- Vegetation and habitat
  - $V_{grasscont}$ - Continuity of Grassland Around the Wetland
  - $V_{grasswidth}$ - Width of Grassland around the Wetland
  - $V_{vegcomp}$ - Vegetation Composition of the Wetland
- Soils
  - V_{sed} - Sediment Deposition in the Wetland
  - V_{pore} - Soil Pores and Structure
- Hydrologic
  - V_{mod} - Wetland Modifications
  - V_{out} - Wetland Outlet
  - V_{source} - Reduction or Increase in Catchment Area
- Landscape and land use
  - $V_{wetarea}$ - Wetland Density in the Landscape
  - $V_{wetprox}$ - Proximity to Nearest Wetlands
  - V_{wetuse} - Land Use Within the Wetland
  - V_{upuse} - Land Use Within the Catchment

Data Analysis

Entry

Follow the assessment protocols given above to complete a wetland functional assessment using this Guidebook. It is critical that all data entries are made on the field forms provided with this Guidebook in Appendix B. This will greatly reduce confusion about what data need to be collected and will assist the user to prevent accidentally skipping over necessary field data while visiting the WAA. Much of the initial site characterization and map data will come from pre-existing databases, internet sources (e.g., USGS, NRCS), or office source materials (e.g., NWI maps, County soil survey maps). The time necessary to collate these materials and analyze the maps and complete data entry of Landscape Scale variables from preexisting databases is generally 2 to 3 hr. Collection of field data for a single Rainwater Basin wetland of moderate size and complexity will generally require two people as much as 2 to 4 hr of field time to complete.

Analysis

The primary objective of the HGM Approach to the Functional Assessment of Wetlands is the determination of Functional Capacity Indices (FCI), which when combined with area produces a Functional Capacity Unit (FCU), which in turn provides a basis for determination of impact and mitigation.

Manual determination of FCI

After the above protocols have been completed to collect all data, and the field data forms found in Appendix B have been completed, fill out the Functional Capacity Index worksheet, also provided in Appendix B should be completed. The FCI worksheet prompts the user to determine variable subindex scores corresponding with each variable. The metric to variable subindex score relationships are based on the reference wetland data set collected during the development of this Guidebook. The variable subindex scores are employed in the six Functional Capacity Index algorithms discussed and explained in Chapter 4 and Appendix B of this Guidebook. The user can then determine, by hand calculation, the FCI of each function.

Spreadsheet determination of FCI

The data sheets are designed to assist the user enter the raw data collected from each site. The equations needed to calculate the variable subindex for each wetland function are already entered into this spreadsheet. The presence of these equations are designated by gray blocks within the spreadsheet (Figure 17). All other blocks indicate where the user is expected to enter data. Instructions for each function are included in the spreadsheet and follow the format of the data sheets found in Appendix B. Each category, along with the corresponding variables, is located in one of the six worksheets. These worksheets are labeled by category. The six FCIs are also entered in the spreadsheet and can be found in the worksheet labeled 'Functions'. After each variable subindex has been calculated using the raw data entered by the user, the FCI's will be automatically computed.

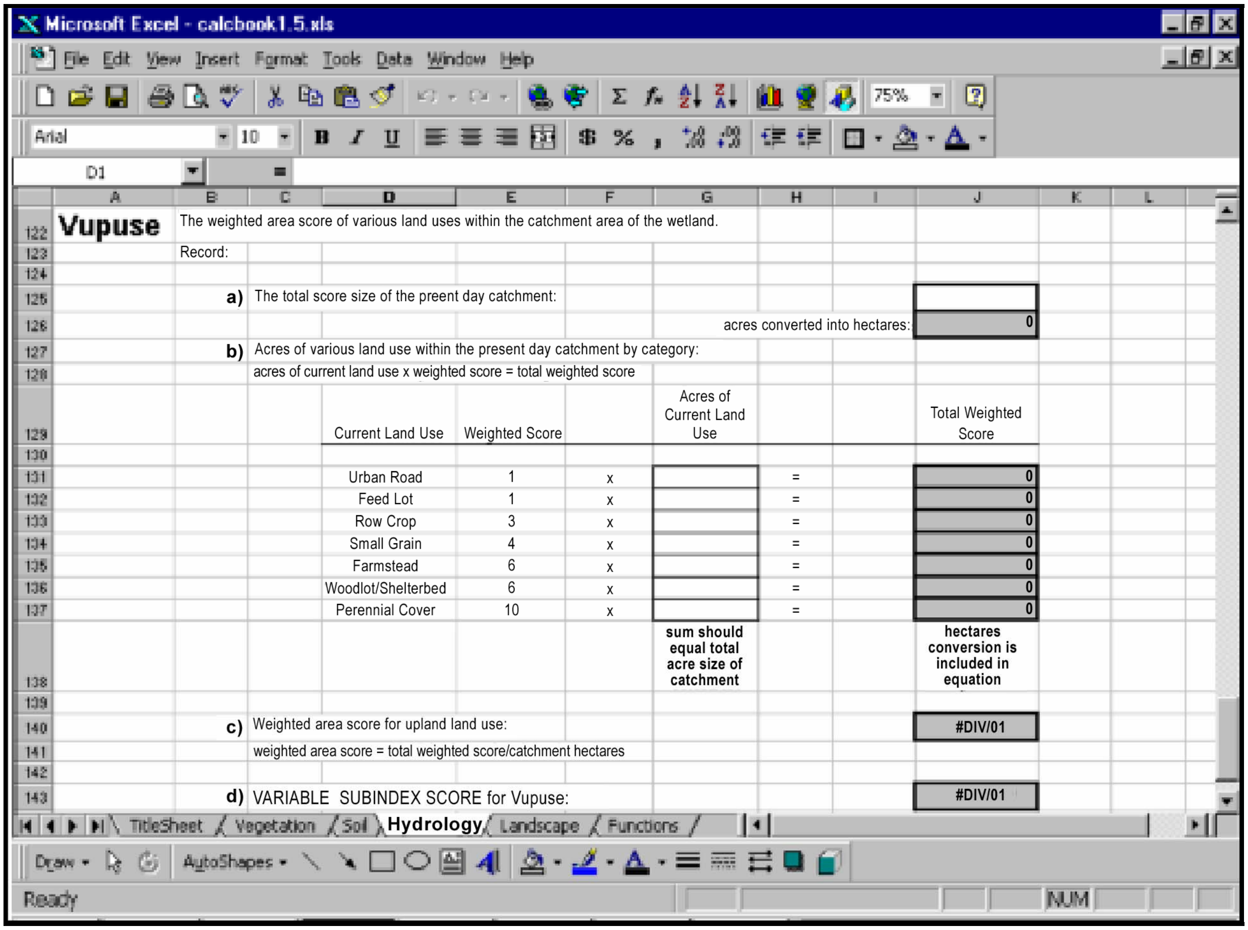


Figure 17. Sample spreadsheet for variable data entry and calculation of FCIs

Apply the Results of the Assessment

Once the assessment and analysis phases are complete, the results can be used to compare the same wetland assessment area at different points in time, comparing different wetland assessment areas at the same point in time, comparing different alternatives to a project, or comparing different hydrogeomorphic classes or subclasses as per Smith et al. (1995).

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Appendix A
Glossary

A Horizon: A mineral soil horizon at the soil surface or below the O horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

Assessment Model: A simple model that defines that relationship between ecosystem and landscape scale variables and functional capacity of a wetland. The model is developed and calibrated using reference wetlands from a reference domain.

Assessment Objective: The reason for conducting an assessment of wetlands functions. Assessment objectives normally fall into one of three categories. These include: documenting existing conditions, comparing different wetlands at the same point in time (i.e., alternatives analysis), and comparing the same wetland at different points in time (i.e., impact analysis or mitigation success).

Assessment Team (A-Team): An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, definition of reference standards, and calibration of assessment models.

Direct Impacts: Project impacts that result from direct physical alteration of a wetland such as the placement of dredge or fill.

Direct Measure: A quantitative measure of an assessment model variable.

Functional Assessment: The process by which to measure the capacity of a wetland to perform a function. The approach measures capacity using an assessment model to determine a functional capacity index.

Functional Capacity: The rate or magnitude at which a wetland ecosystem performs a function. Functional capacity is dictated by characteristics of the wetland ecosystem and the surrounding landscape and interaction between the two.

Functional Capacity Index (FCI): An index of the capacity of a wetland to perform a function relative to other wetlands from a regional wetland subclass in a reference domain. Functional capacity indices are by definition scaled from 0.0 to 1.0. An index of 1.0 indicates that the wetland performs a function at the highest sustainable functional capacity, the level equivalent to a wetland under reference standard conditions in a reference domain. An index of 0.0 indicates the wetland does not perform the function at a measurable level, and will not recover the capacity to perform the function through natural processes.

Highest Sustainable Functional Capacity: The level of functional capacity achieved across the suite of functions by a wetland under reference standard conditions in a reference domain. This approach assumes that the highest sustainable functional capacity is achieved when a wetland ecosystem and the surrounding landscape are undisturbed.

Hydrogeomorphic Wetland Class: The highest level in the hydrogeomorphic wetland classification system. There are five basic hydrogeomorphic wetland classes including depression, fringe, slope, riverine, and flat.

Hydrogeomorphic Unit: Hydrogeomorphic units are areas within a wetland assessment area that are relatively homogenous with respect to ecosystem scale characteristics such as microtopography, soil type, vegetative communities, or other factors that influence function. Hydrogeomorphic units may be the result of natural or anthropogenic processes. See Partial Wetland Assessment Area.

Indicator: Indicators are observable characteristics that correspond to identifiable variable conditions in a wetland or the surrounding landscape.

Indirect Measure: A qualitative measure of an assessment model variable that corresponds to an identifiable variable condition.

Indirect Impacts: Impacts resulting from a project that occur concurrently, or at some time in the future, away from the point of direct impact. For example, indirect impacts of a project on wildlife can result from an increase in the level of activity in adjacent, newly developed areas, even though the wetland is not physically altered by direct impacts.

In-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetland of the same regional wetland subclass.

Invert: The bottom of a channel, pipe, or culvert.

Interflow: The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake.

Jurisdictional Wetland: Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987),[1] or its successor.

Mitigation: Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Mitigation Plan: A plan for replacing lost functional capacity resulting from project impacts.

Mitigation Ratio: The ratio of the FCUs lost in a Wetland Assessment Area (WAA) to the FCUs gained in a mitigation wetland.

Mitigation Wetland: A restored or created wetland that serves to replace functional capacity lost as a result of project impacts.

Model Variable: see Assessment Model Variable.

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[1] References cited in this appendix are in References section following main text.

O Horizon: A layer with more than 12 to 18 percent organic carbon (C) (by weight: 50 percent by volume). Form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc., partially decomposed plant debris (Oe), or totally decomposed organic material (Oa) such as muck.

Off-site Mitigation: Mitigation that is done at a location physically separated from the site at which the original impacts occurred, possibly in another catchment.

Out-of-kind Mitigation: Mitigation in which lost functional capacity is replaced in a wetlands of a different regional wetland subclass.

Partial Wetland Assessment Area (PWAA): A portion of a WAA that is identified *a priori*, or while applying the assessment procedure, because it is relatively homogeneous, and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally, or as a result of anthropogenic disturbance. See Hydrogeomorphic Unit.

Project Alternative(s): Different ways in which a given project can be done. Alternatives may vary in terms of project location, design, method of construction, amount of fill required, and others.

Project Area: The area that encompasses all activities related to an ongoing or proposed project.

Project Target: The level of functioning identified for a restoration or creation project. Conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

Red Flag Features: Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria. The recognition or protection may occur at a Federal, State, regional, or local level, and may be official or unofficial.

Reference Domain: The geographic area from which reference wetlands are selected. A reference domain may or may not include the entire geographic area in which a regional wetland subclass occurs.

Reference Standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functional capacity (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass. The highest level of functional capacity is assigned an index value of 1.0 by definition.

Reference Wetlands: Wetland sites that encompass the variability of a regional wetland subclass in a reference domain. Reference wetlands are used to establish the range of conditions for construction and calibration of functional indices and to establish reference standards.

Region: A geographic area that is relatively homogenous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional Wetland Subclass: Wetlands within a region that are similar based on hydrogeomorphic classification factors. There may be more than one regional wetland subclass identified with each hydrogeomorphic wetland class, depending on the diversity of wetlands in a region and assessment objectives.

Site Potential: The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors. Site capacity may be equal to or less than levels of functioning established by reference standards for the reference domain, and it may be equal to or less than the functional capacity of a wetland ecosystem.

Throughflow: The lateral movement of water in an unsaturated zone during and immediately after a precipitation event. The water from throughflow seeps out at the base of slopes and then flows across the ground surface as return flow, ultimately reaching a stream or lake. See Interflow for Comparison.

Variable: An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of a wetland to perform a function.

Variable Condition: The condition of a variable as determined through quantitative or qualitative measures.

Variable Index: A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

Wetland Ecosystem: "Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas" (Corps Regulations 33 CFR 328.3 and EPA Regulations 40 CFR 230.3). In a more general sense, wetland ecosystems are three-dimensional segments of the natural world where the presence of water, at or near the surface, creates conditions leading to the development of redoximorphic soil conditions, and the presence of a flora and fauna adapted to the permanently or periodically flooded or saturated conditions.

Wetland Assessment Area (WAA): The wetland area to which results of an assessment are applied.

Wetland Banking: The process of establishing a 'bank' of created, enhanced, or restored wetlands to serve at a future date as mitigation of project impacts.

Wetlands Functions: The normal activities or actions that occur in wetlands ecosystems, or simply the things that wetlands do. Wetland functions result directly from the characteristics of a wetland ecosystem and the surrounding landscape, and their interaction.

Wetland Creation: The process of creating a wetland in a location where a wetland did not previously exit.

Wetland Enhancement: The process of increasing the capacity of a wetland to perform one or more functions. Wetland enhancement can increase functional capacity to levels greater than the highest sustainable functional capacity achieved under reference standard conditions, but this happens usually at the expense of sustainability, or a reduction of functional capacity of other functions.

Wetland Restoration: The process of restoring wetland function in a degraded wetland.

Wetland Values: The worth of wetland functions to an individual or society.

Appendix B
Summaries and Forms for Field Use

This appendix contains the following information summaries and example sheets:

Summary of Functions for Rainwater Basin Depressional Wetlands

Function 1: Water Storage

Definition: The function "Water Storage" is defined as the capacity of depressional Rainwater Basin wetlands to store water (both short-term dynamic and long-term static), primarily under the influence of precipitation or snow-melt within the catchment. Storage is normally lost to evapotranspiration or to seepage into the substrate when the pool extends beyond the outer boundary of the hydric soils. Short-term dynamic storage alters the amount of runoff from the landscape into streams. Long-term static storage adds moisture to the soil's unsaturated zone, has a significant effect on biogeochemical cycling, and in particular has a very strong effect on floral and faunal populations.

Model variables - symbols - measures -units:

- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent
- Wetland Modifications - V_{mod} - alterations within the wetland - unitless
- Source Area of Flow - V_{source} - reduction or increase in catchment - percent
- Sediment - V_{sed} - depth to *Bt* horizon - inches (centimeters)
- Upland Land Use - V_{upuse} - land use of uplands within the catchment - weighted area score
- Soil Pores and Structure - V_{pore} - physical soil quality index - soil property criteria

Assessment model:

$$FCI = \sqrt{V_{out} \times \sqrt{\sqrt{V_{mod} \times V_{source}} \times \frac{\left(V_{sed} + V_{upuse} + V_{pore}\right)}{3}}} \tag{B1}$$

Function 2: Cycle Nutrients

Definition: "Cycle Nutrients" is defined as the ability of the depressional wetland to convert nutrients from inorganic forms to organic forms and back, through a variety of biogeochemical processes such as photosynthesis and microbial decomposition.

Model variables - symbols - measures - units:

- Vegetation Composition- $V_{vegcomp}$ - quality of the dominant vegetation - unitless
- Wetland Land Use - V_{wetuse} - land use within the wetland - weighted area score

- Soil Pores and Structure - V_{pore} - physical soil quality index - soil property criteria
- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent

Assessment model:

$$\mathrm{FCI} = \frac{\left(\frac{V_{vegcomp} + V_{wetuse}}{2}\right) + \left(\frac{V_{pore} + V_{out}}{2}\right)}{2} \tag{B2}$$

Function 3: Remove, Convert, and Sequester Elements, Compounds, and Particulates

Definition: "Remove, Convert, and Sequester Elements, Compounds, and Particulates" is defined as the ability of the depressional wetland to permanently remove or temporarily immobilize nutrients, particulates, and other elements and compounds that are imported from upland sources. Elements include nitrogen, phosphorus, and potassium. Compounds include herbicides and pesticides that can be toxic in high amounts. Inorganic and organic particulates are physically immobilized.

Model variables - symbols - measures - units:

- Grassland Width - $V_{grasswidth}$ - mean width of the buffer - feet (meters)
- Grassland Continuity - $V_{grasscont}$ - continuousness of the buffer - percent
- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent
- Source Area of Flow - V_{source} - reduction or increase in catchment - percent
- Upland Land Use - V_{upuse} - land use of uplands within the catchment - weighted area score
- Wetland Land Use - V_{wetuse} - land use within the wetland - weighted area score
- Soil Pores and Structure - V_{pore} - physical soil quality index - soil property criteria
- Sediment - V_{sed} - depth to *Bt* horizon - inches (centimeters)

Assessment model

$$FCI = \frac{V_{grasswidth} + V_{grasscont} + V_{out} + V_{source} + V_{upuse} + V_{wetuse} + \left(\frac{V_{pore} + V_{sed}}{2}\right)}{7} \tag{B3}$$

Function 4: Maintain Characteristic Plant Community

Definition: "Maintain Characteristic Plant Community" is defined as the capacity of a Rainwater Basin wetland to provide the environment necessary for characteristic plant communities to develop and persist. In assessing this function, one must consider not only the extant plant community as an indicator of current conditions but also the physical factors and land use that determine whether or not characteristic plant communities have the potential to be maintained through management or restoration.

Model variables - symbols - measures - units:

- Upland Land Use - V_{upuse} - land use of uplands within the catchment - weighted area score
- Grassland Continuity - $V_{grasscont}$ - continuousness of the buffer - percent
- Grassland Width - $V_{grasswidth}$ - mean width of the buffer - feet (meters)
- Sediment - V_{sed} - depth to Bt horizon - inches (centimeters)
- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent
- Wetland Land Use - V_{wetuse} - land use within the wetland - weighted area score
- Vegetation Composition - $V_{vegcomp}$ - quality of the dominant vegetation - unitless

Assessment Model:

$$FCI = \frac{\left[\dfrac{\left(\dfrac{V_{upuse} + V_{grasscont} + V_{grasswidth}}{3}\right) + \left(\dfrac{V_{sed} + V_{out}}{2}\right) + V_{wetuse}}{3}\right] + V_{vegcomp}}{2} \quad \text{(B4)}$$

NOTE: When doing a functional assessment of a wetland, this model should be computed for all plant communities within the assessment area.

Function 5: Maintenance of Wildlife Habitat Within the Wetland

Definition: The function "Maintenance of Wildlife Habitat within the Wetland" reflects the ability of an **individual** Rainwater Basin wetland to support native wildlife species during some part of their life cycle. The focus of this model is on birds, based on the assumption that, if conditions are appropriate to support the full complement of bird species found in reference standard wetlands, the requirements of other animal groups (e.g., mammals, reptiles, amphibians) will be met. In addition, there is more information available for bird use of the Rainwater Basin than is available for the other animal groups.

Because most prairie wetland animals are highly mobile and their wetland use is often seasonal, direct counts of animals are not recommended. Instead, this function focuses on examining variables that are less subject to these fluctuations.

Model variables - symbols - measures - units:

- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent
- Wetland Land Use - V_{wetuse} - land use within the wetland - weighted area score
- Sediment - V_{sed} - depth to *Bt* horizon - inches (centimeters)

- Vegetation Composition - $V_{vegcomp}$ - quality of the dominant vegetation - unitless
- Upland Land Use - V_{upuse} - land use of uplands within the catchment - weighted area score
- Grassland Width - $V_{grasswidth}$ - mean width of the buffer - feet (meters)
- Grassland Continuity - $V_{grasscont}$ - continuousness of the buffer - percent

Assessment model:

$$\text{FCI} = \frac{V_{out} + \left\{ \frac{V_{wetuse} + V_{sed} + \left[\frac{V_{vegcomp} + V_{upuse} + \left(\frac{V_{grasswidth} + V_{grasscont}}{2} \right)}{3} \right]}{3} \right\}}{2} \tag{B5}$$

Function 6: Maintenance of Wildlife Habitat within the Landscape (OPTIONAL)

Definition: The function "Maintenance of Wildlife Habitat Within the Landscape" reflects the ability of an individual Rainwater Basin wetland, in association with the surrounding **landscape**, to support native wildlife species during some part of their life cycle. The focus of this model is on birds, based on the assumption that, if conditions are appropriate to support the full complement of bird species found in reference standard wetlands, the requirements of other animal groups (e.g., mammals, reptiles, amphibians) will be met. In addition, there is more information available for bird use of the Rainwater Basin than is available for the other animal groups. Because most prairie wetland animals are highly mobile and their wetland use is often seasonal, direct counts of animals are not recommended. Instead, this function focuses on examining variables that are less subject to these fluctuations.

Model variables - symbols - measures - units:

- Regional Wetland Area - $V_{wetarea}$ - wetlands within a 4.83-km (3-mile) radius – hectare (acres)acres
- Nearest Wetland Neighbors - $V_{wetprox}$ - mean distance to nearest five wetlands - meters
- Upland Land Use - V_{upuse} - land use of uplands within the catchment - weighted area score
- Wetland Outlet - V_{out} - presence of natural or constructed outlets - percent

Assessment model:

$$FCI = \frac{2V_{wetarea} + 2V_{wetprox} + V_{upuse} + V_{out}}{6} \tag{B6}$$

Summary of Model Variables, Measure/Units, Methods, and Terms

Each of the HGM variables used in this Guidebook are presented on the following pages. A summary of the measures and units as well as methods for collection of data are provided. Users should also note that the majority of data forms emulate the pages from the electronic spreadsheet that relates the variable metric to the variable subindex score. The only exceptions are the field forms for collection of vegetation composition and soils profile descriptions. The intent of data forms largely complementing spreadsheets is for ease of calculations and assurance that all necessary information is recorded.

Vegetation Variables

1. Grassland Continuity ($V_{grasscont}$)

Measure/Units: The continuity of grassland expressed as a percentage of the wetland perimeter.

Method:

(1) This variable represents the average continuity of grassland around the perimeter of the wetland. Grassland continuity is measured by determining the perimeter(meters) of the wetland boundary that is contiguous with grassland.

(2) Divide the total distance of grassed perimeter by the total wetland perimeter to obtain the "percent of wetland boundary that has a grass edge" calculated. This variable can be measured in the field or from appropriate scale aerial photography. Any off-site measurements should be verified in the field.

Data Form:

$V_{grasscont}$ Grassland continuity.
Record:

a) The perimeter of the wetland (meters): [ ]

USER NOTE: **multiply feet by 0.305 to convert into meters**

b) Meters of grassland (perennial cover) along perimeter: [ ]

c) Divide **b)** by **a)** and multiply by 100% to calculate percent continuity: [#DIV/0!] %

d) VARIABLE SUBINDEX SCORE for $V_{grasscont}$: [#DIV/0!]

y = 0.01x

USER NOTE: **Alternative Method: Using the 12 points measured for grassland width, divide the total number of points with a score greater than 0 by 12 to estimate the percent of the perimeter with a grassed edge.**

2. Grassland Width ($V_{grasswidth}$)

Measure/Units: Average grassland width in meters perpendicular from the wetland edge.

Method:

(1) Assign 12 points placed at equal intervals around the perimeter of the wetland boundary. It is recommended that the first point be located on the northern edge of the wetland and that the remaining points correspond to the hours of a clock.

(2) From each point, measure, perpendicular from the edge of the wetland, the width of the adjacent grassland from the edge of the wetland out to a distance of 30 m. If crops, roads, or feedlots are present at the edge of the wetland, then no grassland edge is present and a score of 0 is generated for that point. The average width of grass (perennial cover) from the 12 points is then calculated. This variable can be measured in the field or from appropriate scale aerial photography. Any off-site measurements should be verified in the field.

Data Form:

$V_{grasswidth}$ Grassland width.
Record:

a) Grassland (perennial cover) width in meters at 12 points:

USER NOTES: measurement for each point should not exceed 30 meters.
Multiply feet by 0.305 to convert into meters.

Point 1 (North, 12:00):	
Point 2 (1:00):	
Point 3 (2:00):	
Point 4 (3:00):	
Point 5 (4:00):	
Point 6 (5:00):	
Point 7 (6:00):	
Point 8 (7:00):	
Point 9 (8:00):	
Point 10 (9:00):	
Point 11 (10:00):	
Point 12 (11:00):	
Mean Width:	#DIV/0!

b) VARIABLE SUBINDEX SCORE for $V_{grasswidth}$: #DIV/0!

y = 0.0328 x - 0.0032

3. Vegetation Composition ($V_{vegcomp}$)

Measure/Units: Weighted percent concurrence with reference standard and other native (excluding invasive) dominant species. This is determined for each plant community identified within the wetland. Both field and spreadsheet forms are provided.

Methods:

(1) Dominant species are those which are most abundant and contribute most to the character of the wetland. Based upon off-site information and field reconnaissance, the investigator should identify and map the distinct plant communities (zones) within the wetland. The plant community(ies) is considered the sample unit. Next, visually select and record dominant species within each distinct plant community. Where quantitative data are available, it is recommended that species with greater than 20 percent relative composition be considered dominant species.

(2) Species records from reference data collection and Gilbert (1989)[1] were independently assigned a coefficient of conservatism (termed C-value). Species are ranked on a scale of 0 to 10, with a '0' assignment being taxa that are adapted to severe disturbances (particularly anthropogenic) and a '10' representing high species fidelity to a natural area. See Taft et al. (1997) for a more detailed description on floristic quality assessment. C-values are based on Rolfsmeier and Steinauer (2003) assignments for Nebraska's flora. Modifications were made to the state list in the instances where native species were considered invasive emergents (e.g.*Scirpus fluviatilis*). Also, all native woody species were considered not characteristic of this depressional subclass and subsequently assigned a C-value of 0.

(3) From the coefficient of conservatism assignment, floristic quality indicators were established based upon the following categories in the following tabulation:

Indicator Category (dominant species only)	Abbreviation	Floristic Quality Indicator criteria
Reference Standard Species	RSS	C-value $\geq$3
Native Nonivasive Secies	NN	C-value < 3
Exotic/Invasive Secies	EI	Nonnatives, Invasive natives

A listing of the C-values assignments and the above indicators are provided in Appendix C of this document.

[1] References cited in the appendices are in References Section following main text.

(4) For the dominant species listed in each wetland plant community, assign the appropriate indicator category abbreviations on the data sheet.

(5) For each individual plant community within the mapped wetland assessment area (WAA), determine the relative area (percent). For $V_{vegcomp}$, in areas void of vegetation, namely open water and drawdown phases, these cover types should be noted on mapping data but **excluded** from sampling and relative percent area calculations. Open water and drawdown phases that are **not void** of vegetation should be included in calculations. Recognize that even though species present may have a low raw cover value within the community, these species would still be considered dominant species when relative cover is relativized.

(6) To assess the floristic quality of each individual plant community within the wetland assessment area:

(a) Count and record the number of 'RSS' dominant species

(b) Count the **number** of 'n' dominant species

(c) Multiply the number of 'NN' species by 0.5, record

(d) Add the number of 'RSS' species with the numeric value from step 6*c*. This is your numerator.

(e) This numerator is then divided by the total number of dominant species from all three indicator categories. This number is the weighted index average.

(f) The weighted index average is then multiplied by the percent area. This value is an area based weighted score. Steps 6*a-f* are summarized in the following formula:

$$\text{Plant community weighted score} = \frac{\#\text{ of RSS dom. species} + \frac{1}{2}(\#\text{ of NN dom. species})}{\text{total }\#\text{ of dom. species}} \times \text{Percent area} \qquad \text{(B7)}$$

(7) Sum all plant communities' weighted scores. This summation value represents the $V_{vegcomp}$ subindex score. The formula for this calculation would be represented as:

$$V_{vegcomp}: \sum ((\#RSS_i + 0.5(\#NN_i)) / n_{ij}) * Percent\ area_j \tag{B8}$$

where:

$V_{vegcomp}$	=	Sum of the weighted scores for each plant community j in the wetland assessment area
$\#RSS_i$	=	Number of reference standard dominant species in the plant community
$\#NN_i$	=	Number of native dominant species in the plant community
$\#RSS_i + 0.5(\#NN)_i$	=	Weighted percent concurrence in the plant community
n_{ij}	=	Total number of dominant species in the plant community $_j$
$Percent\ area_j$	=	Relative area of the plant community $_j$

Data Form:

$V_{vegcomp}$ Sum each species category for each plant community sampled and enter this data into the equation table below.

Dominant species categories: Reference standard species (RSS)
Native-neutral species (NN)
Exotic-invasive species (EI)

equation variables: **RSS** = total number of Reference standard species that dominate the plant community
NN = total number of Native-neutral species that dominate the plant community
n = total number of dominant species in the plant community (RSS+NN+EI)
% area = percent of the total wetland area that the plant community occupies

	RSS	+	1/2	NN	/	n	=	(subtotal)	x	% area	=	
Plant Community #1:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
Plant Community #2:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
Plant Community #3:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
Plant Community #4:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
Plant Community #5:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
Plant Community #6:		+	1/2		/		=	#DIV/0!	x		=	#DIV/0!
										(Sum = 100%)	Sum =	0.00

VARIABLE SUBINDEX SCORE for $V_{vegcomp}$: 0.00

y = x

Field Form:

Site Name:	**Date:**	**Location:**

Plant Community:		Plant Community:		Plant Community:	
Percent of wetland area:	n =	Percent of wetland area:	n =	Percent of wetland area:	n =
Plant	Category	Plant	Category	Plant	Category
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	

Plant Communtiy:		Plant Communtiy:		Plant Communtiy:	
Percent of wetland area:	n =	Percent of wetland area:	n =	Percent of wetland area:	n =
Plant	Category	Plant	Category	Plant	Category
1		1		1	
2		2		2	
3		3		3	
4		4		4	
5		5		5	
6		6		6	
7		7		7	

* Dominant species are those which are most abundant and contribute most to the character of the community independently from each plant community (See Reference Species List in Appendix C (Table C3) for Indicator values)

Equation: [RSS + (1/2 NN)] / total number of dominant species x Percent area

	RSS	NN	n	Subtotal*	Percent area	
Plant Community ____						
Plant Community ____						
Plant Community ____						
Plant Community ____						
Plant Community ____						
Plant Community ____						
Plant Community ____						
					(100 Percent	(a)

* Calc book will fill in the gray boxes

(a) = Subindex Score

Soil Variables

1. Physical soil quality and extent of sediment (V_{pore} and V_{sed})

Measure/Units: V_{pore} is the quality of the soil surface layer (A or Ap horizon) as measured by a unitless summation index; and, Vsed is the depth of sediment from natural and culturally accelerated sources as inferrred from the depth to the *Bt* horizon (cm). These variables should be evaluated in the same soil pits. Both variables are evaluated in the outer depressional soil or vegetational zone (usually the Fillmore soil or the temporary zone) of the wetland.

Methods: Dig soil holes with a sharp shooter spade to a depth of at least 50 cm (20 in.). Dig to the top of the *Bt* horizon and remove a vertical slice of soil for further verification. The soil profile should be described in accordance with delineation protocol and the appropriate documnetation of characteristics necessary for computation of the Physical Soil Quality Index (PSQI). Check the soil profile in the most and least impacted areas near the outside edge of the outer depressional soil or vegetative zone. The outside edge corresponds to the hydric soil boundary of the wetland and can be checked with the soil by using hydric soil indicators. Measure the depth to Bt horizon for the number of replicates required. The depth to *Bt* and PSQI's should be averaged for calaculation of the final subindex score.

Data Forms:

V_{sed}

The extent of sediment from natural and culturally accelerated sources in the outer depressional soil or vegetative zone (usually the Fillmore soil or the temporary zone) of the wetland.

Determine the most impacted area by any visual sediment deposition on the surface such as fans, staining or burial of detritus, plant crowns, stems and leaves. If no visual sediment is present, then excavate near the middle of the outer depressional soil or vegetative zone. Some wetlands may not have a Fillmore soil mapped. Look for the vegetation that is usually found in the temporary zone. Also, determine the least impacted area and excavate a pit.

Measure the depth to Bt horizon (cm.) in at least two pits. Calculate the mean depth to Bt horizon and record below.

Record:

Mean Depth to *Bt* horizon (centimeters):	
VARIABLE SUBINDEX SCORE for V_{sed}:	0.00

if <=32, y = 0.0296 x + 0.2669
if >32, y = -0.0442 x + 2.4759

V_{pore}

The physical quality of the soil surface layer (A or Ap horizon) in a typical plant community within a wetland.

Comprehensive Method for V_{pore} Variable

The Physical Soil Quality Index (PSQI) is a method to access anthropogenic impacts to near-surface soil physical properties that reflect soil porosity and the ability of the soil to allow infiltration and movement of water.

Determine the PSQI for each soil property and then total. Do for at least two pits.

The possible range for PSQI is a minimum of 6 and a maximum of 25. Actual range is 9 to 23. The higher the number, the better the PSQI.

Mean PSQI for the Site:

VARIABLE SUBINDEX SCORE for V_{pore}: 0.00

$y = 0.0588x - 0.3529$

Field Form:

Site Name			Date:			Location:					
						Sec.	T.	R.			

Pedon ID #:											
PEDON	Depth	Ap	Pores		Structure				Consistence	Roots	PSQI
DESCRIPTION	cm	Y or N	Qty	Cont	Compound	Grade	Size	Shape	Type	Quantity	SUM

Pedon ID #:											
PEDON	Depth	Ap	Pores		Structure				Consistence	Roots	PSQI
DESCRIPTION	cm	Y or N	Qty	Cont	Compound	Grade	Size	Shape	Type	Quantity	SUM

Pedon ID #:											
PEDON	Depth	Ap	Pores		Structure				Consistence	Roots	PSQI
DESCRIPTION	cm	Y or N	Qty	Cont	Compound	Grade	Size	Shape	Type	Quantity	SUM

Pedon ID #:											
PEDON	Depth	Ap	Pores		Structure				Consistence	Roots	PSQI
DESCRIPTION	cm	Y or N	Qty	Cont	Compound	Grade	Size	Shape	Type	Quantity	SUM

Soil	Assigned PSQI numbers for soil property criteria			
Property	0	1	2	3
Ap	~	present	absent	~
Pores	~	few	common	many
Pore continuity	~	low	moderate	high
Compound structure	~	no	yes	~
Structure grade	massive	weak	moderate	high
Structure size	massive or thick	coarse	medium	fine or thin
Structure shape	massive	platy	subangular blocky	granular
Consistence	~	firm	friable	very friable
Roots	~	few	common	many

USER NOTES:

1) Form is to be used for both Vpore and Vsed
2) PSQI #'s are at the right
3) Depth to Bt is derived from the pedon description
4) For data entry into the spreadsheet, PSQI values and depth to Bt should be averaged for the site.
5) Site conditions may require dividing the area in PWAA's

Hydrology Variables

Wetland Modifications (V_{mod})

Measure/Units: The presence or absence of various alterations such as dikes, water control structures, artificial water inputs, or water removal by pumping is noted. The effects the alterations have on the wetland is determined from categories.

Method: A combination of off-site and on-site assessment methodology can be used for this variable:

(1) Review aerial photography, USGS map, soil map, scope and effect map, and National Wetland Inventory (NWI) map.

- *(a)* Note and document the presence of any dikes or other fill within the hydric soil footprint and the effects on the wetland.
- *(b)* Note and document wetland water regime class.
- *(c)* From the USGS topographic map, delineate the original catchment area or use an aerial photo in the field and sketch the catchment.
- *(d)* Note the presence of water control structures and the input of irrigation runoff, or the removal of water by pumping.

(2) Record:

- *(a)* The presence of dikes or other fill material within the hydric soil footprint.
- *(b)* The presence of, and invert elevation of, culverts or water control structures.
- *(c)* The input of irrigation runoff into the wetland.
- *(d)* The use of artificial pumping to remove water from the wetland.
- *(e)* Note groundwater input (western basins).

Data form:

V_{mod}

The presence, or absence of various alterations within the wetland such as dikes, water control structures, artificial water input, or water removal by pumping is noted and the affects the alterations have on the wetland. Record:

Alterations	Subindex
Natural conditions present, no dikes or fill within the wetland that restrict or redirect flow or change the wetland water regime class, no pumping or groundwater inputs -OR- wetland has been fully restored.	1.0
Dike or fill bisects the wetland area and the amount of isolated wetland is proportional to the amount of the isolated catchment area -OR- dike has an unrestricted culvert(s) with the invert at or below natural grade.	0.9
Dike(s) with water control capability keep water on a wetland and does not change the wetland water regime class -OR- increased flows to the wetland supplement or correct altered hydrology.	0.6
Dike(s) or fill bisect wetland and change the wetland water regime class -OR- land leveling has resulted in a land use modification with marginal success -OR- groundwater presence has altered the natural wetland water regime class and soil characteristics -OR- sediment/ soil ridge ponds shallow water outside of the wetland.	0.3
Dike(s) or artificial pumping keep the wetland dry -OR- land leveling or fill has raised the elevation of the bottom of the wetland above the temporary zone.	0.0

Enter subindex derived from the above table:

h) VARIABLE SUBINDEX SCORE for V_{mod}:

Wetland Outlet (V_{out})

Measure/Units: Elevation of wetland outlets, natural or constructed, in relation to edge of the wetland and hydric soils. The volume of excavations present within the hydric soil footprint of the wetland.

Method: (1) Elevations and distances will be determined by approved surveying methods and equipment (not a hand level). Survey the elevation of the invert (the invert is the controlling elevation, or the point which determines the extent of drainage) of any surface outlet(s). Survey the elevation of the outer edge of the temporary and seasonal zones of the present-day wetland. To calculate wetland volume, use the following average depths: Temporary zone (Fillmore soil) – 10.16 cm (4 in. or 0.33 ft), Seasonal zone (Scott soil) – 15 cm (6 in. or 0.5 ft), and Semi-permanent zone (Massie soil) – 30.5 cm (12 in. or 1 ft). Use a dot grid, planimeter, or GIS to determine the surface area of the historical wetland. Use the following formula to calculate the volume of the historic wetland: (surface area) × (avg. depth in meters (feet)) × 0.6. Calculate the volume of excavations using the following formula:

(*Surface area at top of excavation* + *Surface area at bottom of excavation*/2) × (*avg. depth in(meters(feet)*)

(2) Record:

(a) Invert elevation, if one is present, in relation to wetland maximum depth.

(b) Elevation of the edge of the present-day wetland.

(c) Elevation of the edge of the seasonal zone, if present, in the wetland.

(d) Length, width, depth, and total volume of excavations within the wetland.

(e) Volume of the historic wetland.

(f) Percent of historic wetland volume reduction:

(volume of excavations(s) / volume of historic wetland × 100)

Data form:

V_{out}

Elevation of wetland outlets, natural or constructed in relation to edge of the wetland and hydric soils; also, the volume of excavations present within the hydric soil footprint of the wetland.
Record:

USER NOTE: Users can utilize English or Metric units. Volumetric measurements been relativized to percentages.

a) Invert elevation (if one is present) in relation to wetland maximum depth: [ ]

b) Elevation of the edge of the present day wetland: [ ]

c) Elevation of the edge of the seasonal zone (if present) in the wetland: [ ]

d) Total volume of excavations within the wetland:

surface area at top of excavation:	
surface area at bottom of excavation:	
average depth in feet:	
volume of excavations:	0

[(Surface area at top of excavation + Surface area at bottom of excavation)/2] x (Average depth in feet)

e) Volume of the historic wetland:
(Historic surface area) x (Average depth in feet) x 0

historic surface area:	
average depth in feet:	
volume of the historic wetland:	0

f) Historic wetland volume reduction:
(Volume of excavation(s) / Volume of historic wetland) x 100

percent historic volume reduction: #DIV/0! %

g) VARIABLE SUBINDEX SCORE for V_{out}: #DIV/0!

y = -0.0125 x + 1.0

USER NOTE: A Variable Flow tail-water Recovery System is not considered a physical alteration to the wetland. Excavations include tail-water recovery pits, deep road ditches that hold water and do not drain, drainage ditches that do not drain completely, livestock watering pits, or any other artificially created feature that concentrates and holds water.

3. Source Area of Flow (V_{source})

Measure/Units: The percent change (increase, decrease, or both) in the catchment area surrounding a wetland resulting from alterations such as reuse pits, diversions, roads, land leveling, etc. This variable can be scored as a condition or measured by:

$$\textit{Present-day catchmentarea / historic catchmentarea} \times 100$$

Method: These measurements can be taken at any time during the assessment. For efficiency they could be done in the office and checked in the field. If small wetlands on flatter topography do not show contour lines on the USGS topographic maps for delineating catchment area, sketch the catchment on an aerial photo or map in the field.

(1) Review aerial photography, USGS maps, soil maps, scope and effect maps, and NWI maps. Note and document any surface or subsurface alterations. Note and document wetland subclass. From the USGS topographic map delineate the original catchment area or use an aerial photo in the field and sketch the catchment. Count the number of standard-size tail-water recovery pits present within the catchment and convert to a number per square mile (number of pits divided by catchment area in square kilometers (square miles)). To convert existing catchment to square kilometers (square miles), multiply hectare (acres) in catchment by 0.0015625.

(2) Record:

(a) Type and effect of surface alteration(s).

(b) Number of standard size tail-water recovery pits per square mile.

(c) Change in wetland regime class - Yes or No?

(d) Percent of historic catchment area still contributing runoff to the wetland.

(e) Note groundwater input (western basins).

Data Form:

NOTE: If the office review can determine that the catchment area has been altered, determine the amount of catchment area that has been structurally altered to prevent flow to the wetland. In most cases, the index score is determined based on percent of catchment from which water is prevented from reaching the wetland. Also, note areas added to the catchment due to, for example, road ditches or from land leveling and irrigation. In the field, verify all alterations noted during the off-site review and document any additional alteration found during the field investigations.

V_{source} Percent change (increase, decrease, or both) in the catchment area.
Record:

a) Type and effect of surface alterations: ______

b) Number of standard-size tail-water recovery pits per square mile in the catchment: ______

USER NOTE: to convert catchment to square miles: (Catchment area)x(0.0015625)=Sq. Miles
Users can utilize English or Metric units. Volumetric measurements been relativized to percentages.

c) Considering the soil type(s) present, has the wetland regime class been changed from what would be expected on this site due to alterations in the catchment: **YES** or **NO** ______

d) Percent of catchment area intact: ______ %

e) WESTERN BASINS ONLY - note if there is a groundwater input. **YES** or **NO** ______

f) VARIABLE SUBINDEX SCORE for V_{source}: 0.00

if <90, y = 0.0107 x - 0.0366
if >90, y = -0.0084 x + 1.8803

USER NOTES: Surface Alterations include roads, ditches, waterways, field drains, terraces, diversions, land leveling, tail water recovery pits, farm ponds, and irrigation runoff. Standard-Size tail water Recovery Pit is 275' x 70' x 10' (3,518 cy -or- 2.18 acre-feet), adjust TRP count accordingly. An intact catchment is one in which water flowing off the catchment area is able to reach the wetland. For example, if a catchment is divided by a road, but a functioning culvert under the road allows water to pass from one side to the other and still reach the wetland the catchment would be considered intact.

Landscape and Landuse Variables

1. Regional Wetland Area ($V_{wetarea}$)

Measure/Units: The area of palustrine wetlands within a 4.0-km (3-mile) radius from the center of the reference wetland.

Method:

(1) Draw a circle with a radius of 4.0 km (3 miles) from the center of the reference wetland.

(2) Calculate the acres of palustrine wetlands within this circle, excluding the reference wetland, using recoded NWI data. For wetlands bisected by the circle, only the polygons contained on the inside of the circle are included. This is most easily done using GIS.

The NWI data are recoded in the following manner. For polygons with multiple contiguous water regimes, the water regime is recoded to the most permanent emergent water regime. For example, a polygon with a temporary zone (PEMA) surrounding a seasonal zone(PEMC) containing a reuse pit (PUBFx) is all recoded as a (PEMC). In addition, wetlands that have only an excavated (x) or diked (h) modifier are excluded for this analysis.

Data form:

$V_{wetarea}$	Regional wetland area. Record:
	a) The acres of palustrine wetlands within a 4.8-kilometer (3-mile) radius from the center of the reference wetland:
	USER NOTE: **wetlands that have only an excavated (x) or diked (h) modifier are excluded for this analysis.**
	acres converted into hectares: 0.00
	b) VARIABLE SUBINDEX SCORE for $V_{wetarea}$: 0.00
	$y = 0.0012 x + 0.0005$

2. Nearest Wetland Neighbors ($V_{wetprox}$)

Measure/Units: Distance in meters from the center of the reference wetland to the centers of the nearest five wetlands.

Method:

(1) Using the recoded NWI map, measure the distance in feet from the center of the reference wetland to the centers of the nearest five wetlands.

(2) Calculate the mean distance. This is most easily done using GIS.

The NWI data are recoded in the following manner. For polygons with multiple contiguous water regimes, the water regime is recoded to the most permanent emergent water regime. For example, a polygon with a temporary zone (PEMA) surrounding a seasonal zone (PEMC) containing a reuse pit (PUBFx) is all recoded as a (PEMC) (see diagram example). In addition, wetlands that have only an excavated (x) or diked (h) modifier are excluded for this analysis.

Data Form:

$V_{wetprox}$

Nearest wetland neighbors.

Record:

a) Distance in meters from the center of the assessment wetland to the centers of the nearest five wetlands.

USER NOTES: wetlands that have only an excavated (x) or diked (h) modifier are excluded from this analysis. Multiply feet by 0.305 to convert into meters.

Distance to nearest wetland(m.):	
Distance to 2nd nearest wetland:	
Distance to 3rd nearest wetland:	
Distance to 4th nearest wetland:	
Distance to 5th nearest wetland:	
Mean Distance:	#DIV/0!

b) VARIABLE SUBINDEX SCORE for $V_{wetprox}$: #DIV/0!

$y = -0.0007 x + 1.1053$

3. Wetland Land Use (V_{wetuse})

Measure/Units: The weighted area score of various land uses within the present-day wetland area. Land use is determined on the entire hydric soil area of the wetland under assessment.

Method: A combination of off-site and on-site assessment methodology can be used for this variable.

(1) Review aerial photography and the Food Security Act (FSA) land use history for the site. Use a soils map and field methodology to determine the hydric soil boundary of the historical wetland. Use a dot grid, planimeter, or GIS to determine the acreage of the various land use categories as listed in Table 10 in Chapter 4 of this

Guidebook. Then, multiply the acreage in each category by the weighted score and divide by total historic wetland acres to determine a total weighted area score. This value is then applied in Table 10 to derive the subindex score for this variable.

(2) Record:

(a) Total hectares (acres) of present-day wetland.

(b) Hectares (acres) of various land use within the present-day wetland.

(c) Weighted area score for wetland land use.

Data Form:

V_{wetuse} Wetland land use.

Record:

a) Total acres of the present-day wetland:

acres converted into hectares: 0.00

b) Acres of various land uses within the wetland:

Wetland land use	Acres	Weighted Score	(Acres x Weighted Score)
			0.00
			0.00
			0.00
			0.00
			0.00
			0.00
Total:			0.00

acres to hectares conversion is included in equation

Current Land Use	Weighted Score
Fill - creating upland within the wetland	0
Deep Water - deep enough to preclude other land uses	1
Annually Cropped	3
Occasionally Cropped	4
Perennial Cover - idle	5
Perennial Cover - heavily grazed	6
Perennial Cover - moderately grazed or hayed	8
Perennial Cover - managed for wildlife	10

c) Divide (Hectares x Weighted Score) by Total Hectares: #DIV/0!

d) VARIABLE SUBINDEX SCORE for V_{wetuse}: #DIV/0!

y = 0.1259 x - 0.1018

3. Upland Land Use in the Catchment (V_{upuse})

Measure/Units: The weighted area score of various land uses within the catchment of the wetland. Land use determination is made from the outer edge of the wetland to the catchment boundary.

Method: A combination of off-site and on-site assessment methodology can be used for this variable.

(1) Review aerial photography and the FSA land use history for the site. From the USGS topographic map, delineate the present-day catchment area or use an aerial

photo in the field and sketch the catchment. Use a dot grid, planimeter, or GIS to determine the acreage of the various land use categories as listed in Table 11 in Chapter 4 of this Guidebook. Then, multiply the acreage in each category by the weighted score, add all together for a total, and divide by present-day catchment acres to determine a total weighted area score. This value is then used in Table 11 to derive the subindex score for this variable.

(2) Record:

(a) Total hectares (acres) of present-day wetland.

(b) Hectares (acres) of various land use within the present-day wetland.

(c) Weighted area score for wetland land use.

Data Form:

V_{upuse} The weighted area score of various land uses within the catchment area of the wetland.
Record:

a) The total acre size of the present day catchment: [ ]

acres converted into hectares: 0

b) Acres of various land use within the present-day catchment by category:
acres of current land use x weighted score = total weighted score

Current Land Use	Weighted Score		Acres of Current Land Use		Total Weighted Score
Urban/Road	1	x		=	0
Feed Lot	1	x		=	0
Row Crop	3	x		=	0
Small Grain	4	x		=	0
Farmstead	6	x		=	0
Woodlot/Shelterbed	6	x		=	0
Perennial Cover	10	x		=	0
			sum should equal total acre size of catchment		**acres to hectares conversion is included in equation**

c) Weighted area score for upland land use: #DIV/0!
weighted area score = total weighted score / catchment hectares

d) VARIABLE SUBINDEX SCORE for V_{upuse}: #DIV/0!

y = 0.1 x

Appendix C
Reference Wetland Data

This Appendix contains:

Table C1
Reference Site Locations[1]

Site Name	Legal Description	Longitude	Latitude	USGS Quad
Clay 29	NE1/4 of NE1/4 of 24-6-6	-97.93978	40.478691	Edgar NW
Clay 39	SE1/4 of 21-6-6	-97.99757	40.472590	Edgar NW
Clay 78	E1/2 of SE1/4 of 24-6-5	-97.8274	40.470505	Ong
Clay 99	NE1/4 of SE1/4 of 19-6-6	-98.0334	40.472910	Fairfield
Clay 216	SE1/4 of NE1/4 of 25-6-6	-97.94012	40.460030	Edgar NW
Clay 228	NW1/4 of NW1/4 of 34-7-6	-97.99229	40.538483	Saronville
Clay 230	SE1/4 of SW1/4 of 25-7-5	-97.83412	40.539900	Sutton
Clay 231	SE1/4 of SW1/4 of 25-7-5	-97.83339	40.544900	Sutton
Clay 233	E1/2 of NE1/4 of 30-6-7	-98.14781	40.461990	Fairfield NW
Clay 302	NW1/4 & SW1/4 of 29-6-5	-97.91732	40.460730	Edgar NW
Fillmore 23	W1/2 of SW1/4 of 19-6-4	-97.8221	40.469240	Ong
Fillmore 25	NE1/4 of NE1/4 of 24-6-3	-97.60247	40.480129	Strang
Fillmore 28	SE1/4 of 10-6-3	-97.63963	40.497318	Shickley
Fillmore 36	SE1/4 of SE1/4 of 29-6-3	-97.67365	40.454117	Shickley
Fillmore 68	SE1/4 of NW1/4 of 30-8-3	-97.70281	40.634810	Grafton
Fillmore 80	NW1/4 of SW1/4 of 10-7-4	-97.76590	40.587490	Sutton
Fillmore 85	NE1/4 of 5-7-4	-97.78842	40.608498	Sutton
Fillmore 99	SW1/4 of 19-6-2	-97.59306	40.470802	Strang
Fillmore 122	N1/2 of NW1/4 of 3-7-2	-97.53535	40.608501	Geneva
Fillmore 124	SE1/4 of NE1/4 of 7-5-3	-97.69355	40.417233	Shickley
Fillmore 125	E1/2 of SE1/4 of 24-5-4	-97.71088	40.384144	Shickley
Franklin 99	NE1/4 of NE1/4 of 4-4-13	-98.77856	40.34877	Upland SE
Kearney 12	N1/2 of 30-5-15	-99.0541	40.377022	Axtell East
Kearney 16	E1/2 of 28-5-13	-98.78225	40.372765	Upland SE
Kearney 32	N1/2 of 36-7-15	-98.96063	40.538658	Minden North
Kearney 33	W1/2 of NW1/4 of 28-5-13	-98.79874	40.374775	Upland SE
Phelps 9	All of 4-5-18	-99.36831	40.430416	Holdrege East & West
Phelps 13	S1/2 of 10-5-18	-99.35364	40.440495	Holdrege East
Phelps 30	E1/2 of NE1/4 of 16-6-18	-99.35818	40.496471	Holdrege East
York 21	SE1/4 of 27-9-2	-97.52832	40.714508	Fairmont
York 99	SW1/4 of 27-9-2	-97.53796	40.713551	Fairmont
York 100	E1/2 of NE1/4 of 36-9-2	-97.48489	40.709011	Exeter

1 Site names are based on the county of occurrence The numbers are based upon Nebraska Game and Parks Commision inventory data.

Table C2
Reference Data and Variable Subindex Scores

	V Grasscont		V Grasswidth		V Vegcomp		V Pore		V Sed		V Mod	
Reference												
Site	(%)	Subindex	meters	Subindex	(%)	Subindex	PSQI	Subindex	cm	Subindex	(%)	Subindex
CLAY029	0.00	0.00	0.00	0.00	61.00	0.61	19.00	0.76	50.00	0.27	0.85	0.85
CLAY039	0.84	0.84	24.23	0.79	84.00	0.84	21.00	0.88	18.00	0.80	1.00	1.00
CLAY078	0.55	0.55	17.08	0.56	96.00	0.96	21.00	0.88	36.00	0.88	0.85	0.85
CLAY099	1.00	1.00	25.05	0.82	75.00	0.75	22.00	0.94	53.00	0.13	1.00	1.00
CLAY216	0.72	0.72	22.30	0.73	72.00	0.72	22.00	0.94	13.50	0.67	1.00	1.00
CLAY228	0.00	0.00	0.00	0.00	76.00	0.76	19.00	0.76	29.00	1.00	1.00	1.00
CLAY230	1.00	1.00	25.12	0.82	70.00	0.70	19.00	0.76	7.00	0.47	1.00	1.00
CLAY231	0.50	0.50	9.14	0.30	59.00	0.59	22.00	0.94	28.00	1.00	1.00	1.00
CLAY233	1.00	1.00	28.12	0.92	52.00	0.52	23.00	0.99	38.50	0.77	1.00	1.00
CLAY302	0.65	0.65	18.49	0.60	96.00	0.96	21.00	0.88	30.00	1.00	1.00	1.00
FILLMORE023	0.57	0.57	14.81	0.48	88.00	0.88	22.50	0.97	27.00	1.00	0.60	0.60
FILLMORE025	0.41	0.41	12.70	0.41	90.00	0.90	20.00	0.82	28.00	1.00	1.00	1.00
FILLMORE028	0.69	0.69	17.50	0.57	54.00	0.54	20.00	0.82	29.50	1.00	0.85	0.85
FILLMORE036	0.00	0.00	0.00	0.00	33.00	0.33	19.00	0.76	38.00	0.80	0.30	0.30
FILLMORE068	0.23	0.23	10.16	0.33	75.00	0.75	20.00	0.82	50.00	0.27	1.00	1.00
FILLMORE080	1.00	1.00	27.20	0.89	100.00	1.00	18.00	0.71	9.00	0.53	1.00	1.00
FILLMORE085	0.78	0.78	19.99	0.65	60.00	0.60	18.00	0.71	10.00	0.56	0.85	0.85
FILLMORE099	0.73	0.73	18.85	0.61	80.00	0.80	20.00	0.82	29.00	1.00	1.00	1.00
FILLMORE122	0.00	0.00	0.00	0.00	0.00	0.00	17.00	0.65	10.00	0.56	1.00	1.00
FILLMORE124	0.00	0.00	0.00	0.00	75.00	0.75	16.00	0.59	31.00	1.00	0.85	0.85
FILLMORE125	0.00	0.00	0.00	0.00	94.00	0.94	19.00	0.76	25.00	1.00	0.85	0.85
FRANKLIN099	0.00	0.00	0.00	0.00	79.00	0.79	17.00	0.65	42.00	0.62	0.85	0.85
KEARNEY012	0.79	0.79	21.65	0.71	96.00	0.96	18.00	0.71	13.00	0.65	no data	no data
KEARNEY016	0.17	0.17	5.08	0.16	76.00	0.76	18.00	0.71	25.00	1.00	0.85	0.85
KEARNEY032	0.00	0.00	0.00	0.00	63.00	0.63	19.00	0.76	21.00	0.89	0.85	0.85
KEARNEY033	0.00	0.00	0.00	0.00	62.00	0.62	19.00	0.76	18.00	0.80	0.85	0.85
PHELPS009	0.32	0.32	11.25	0.36	3.00	0.03	18.00	0.71	26.00	1.00	no data	no data
PHELPS013	0.59	0.59	11.42	0.37	67.00	0.67	18.00	0.71	10.00	0.56	no data	no data
PHELPS030	0.00	0.00	0.00	0.00	30.00	0.30	15.00	0.53	48.00	0.35	0.85	0.85
YORK021	0.22	0.22	7.62	0.25	72.00	0.72	17.00	0.65	50.00	0.27	0.85	0.85
YORK099	0.73	0.73	22.86	0.75	64.00	0.64	18.00	0.71	31.00	1.00	1.00	1.00
YORK100	0.53	0.53	14.48	0.47	58.00	0.58	19.00	0.76	30.00	1.00	0.85	0.85

(Continued)

Table C2 (Concluded)

	V Out		V Source		V Wetarea		V Wetprox		V Wetuse		V Upuse	
Reference Site	(%)	Subindex	(%)	Subindex	ha	Subindex	meters	Subindex	(wt score)	Subindex	(wt score)	Subindex
CLAY029	12.33	0.85	100.00	1.00	452.36	0.56	494.80	0.77	4.10	0.41	3.00	0.30
CLAY039	5.80	0.93	100.00	1.00	674.44	0.83	935.26	0.46	7.00	0.70	7.10	0.71
CLAY078	0.48	0.99	169.73	0.45	767.86	0.95	231.25	0.95	6.70	0.67	4.50	0.45
CLAY099	0.00	1.00	74.03	0.76	478.70	0.59	567.95	0.72	8.60	1.00	6.60	0.66
CLAY216	0.00	1.00	100.00	1.00	672.53	0.83	299.36	0.91	7.60	0.88	4.20	0.42
CLAY228	0.00	1.00	56.22	0.56	236.08	0.29	153.78	1.00	7.80	0.94	3.00	0.30
CLAY230	0.00	1.00	100.00	1.00	71.40	0.09	325.06	0.89	8.00	1.00	3.90	0.39
CLAY231	0.00	1.00	100.00	1.00	70.77	0.09	386.43	0.84	4.00	0.40	5.10	0.51
CLAY233	15.66	0.80	94.76	1.00	184.29	0.23	238.22	0.95	6.00	0.60	10.00	1.00
CLAY302	0.00	1.00	100.00	1.00	543.21	0.67	257.42	0.93	7.30	0.79	7.90	0.79
FILLMORE023	0.00	1.00	116.11	0.90	813.88	1.00	140.71	1.00	6.80	0.68	3.40	0.34
FILLMORE025	101.74	0.00	62.75	0.63	121.05	0.15	253.21	0.94	6.00	0.60	9.50	0.95
FILLMORE028	5.59	0.93	127.54	0.81	79.38	0.10	1147.42	0.32	5.40	0.54	3.50	0.35
FILLMORE036	1.26	0.98	48.39	0.48	109.14	0.13	1576.56	0.02	3.00	0.30	3.00	0.30
FILLMORE068	7.25	0.91	100.00	1.00	382.84	0.47	250.14	0.94	3.00	0.30	3.20	0.32
FILLMORE080	145.16	0.00	60.78	0.61	236.43	0.29	623.52	0.68	4.00	0.40	10.00	1.00
FILLMORE085	26.33	0.67	100.00	1.00	214.75	0.27	315.84	0.89	5.80	0.58	4.50	0.45
FILLMORE099	0.00	1.00	64.24	0.65	118.89	0.15	800.76	0.56	7.50	0.85	3.30	0.33
FILLMORE122	no data	no data	0.00	0.00	112.21	0.14	no data	no data	3.00	0.30	3.00	0.30
FILLMORE124	147.73	0.00	106.66	1.00	130.69	0.16	746.82	0.59	3.00	0.30	3.00	0.30
FILLMORE125	208.33	0.00	168.61	0.46	123.82	0.15	858.50	0.52	5.20	0.52	3.00	0.30
FRANKLIN099	55.10	0.31	162.22	0.52	88.50	0.11	482.55	0.78	3.00	0.30	3.00	0.30
KEARNEY012	no data	no data	0.00	0.00	113.88	0.14	50.99	1.00	no data	no data	no data	no data
KEARNEY016	23.25	0.71	146.85	0.65	189.91	0.23	208.30	0.97	3.10	0.31	3.10	0.31
KEARNEY032	35.71	0.55	100.00	1.00	108.74	0.13	500.40	0.77	3.00	0.30	3.00	0.30
KEARNEY033	62.10	0.22	111.11	0.95	147.18	0.18	652.26	0.66	4.50	0.45	3.00	0.30
PHELPS009	1.32	0.98	100.00	1.00	71.05	0.09	1009.78	0.41	no data	no data	no data	no data
PHELPS013	2.60	0.97	100.00	1.00	45.97	0.06	168.96	1.00	8.00	1.00	no data	no data
PHELPS030	18.01	0.77	130.84	0.78	84.89	0.10	1141.08	0.32	3.00	0.30	3.00	0.30
YORK021	0.00	1.00	100.00	1.00	247.91	0.31	443.87	0.80	4.70	0.47	3.90	0.39
YORK099	0.00	1.00	60.66	0.61	266.22	0.33	599.91	0.70	8.50	1.00	6.70	0.67
YORK100	0.00	1.00	59.79	0.60	184.19	0.23	781.00	0.57	4.00	0.40	5.90	0.59

Table C3
Rainwater Basin Plant Records

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Abutilon theophrasti	VELVET-LEAF	0	EI
Achillea millefolium	YARROW,COMMON	2	NN
Agropyron cristatum	WHEATGRASS,CRESTED	0	EI
Agropyron elongatum	WHEATGRASS, TALL	0	EI
Agropyron intermedium	WHEATGRASS, INTERMEDIATE	0	EI
Agropyron smithii	WHEATGRASS,WESTERN	3	RSS
Agrostis hyemalis (A. antecedens)	BENTGRASS,WINTER	3	RSS
Agrostis stolonifera	BENTGRASS,SPREADING	0	EI
Alisma subcordatum	WATER-PLANTAIN,SUBCORDATE	5	RSS
Alisma triviale	WATER-PLANTAIN	4	RSS
Alopecurus carolinianus	FOXTAIL,TUFTED	1	NN
Alopecurus pratensis	FOXTAIL,MEADOW	0	EI
Amaranthus retroflexus	AMARANTH,RED-ROOT	0	EI
Amaranthus rudis	AMARANTH	0	NN
Amaranthus sp	PIGWEED	0	NN
Amaranthus spp1	AMARANTH	1	NN
Amaranthus spp2	AMARANTHUS	1	NN
Ambrosia artemisiifolia	RAGWEED,ANNUAL	0	NN
Ambrosia grayi	BURSAGE,WOOLLY-LEAF	0	NN
Ambrosia psilostachya	RAGWEED, NAKED-SPIKE	1	NN
Ambrosia spp	RAGWEED	0	NN
Ambrosia tomentosa	PERENNIAL BURSAGE	0	NN
Ambrosia trifida	RAGWEED,GREAT	0	NN
Ammannia coccinea	AMMANNIA,PURPLE	4	RSS
Amorpha canescens	LEAD PLANT	6	RSS
Andropogon gerardii	BLUESTEM,BIG	5	RSS
Apocynum cannabinum	DOGBANE,CLASPING-LEAF	2	NN
Aristida oligantha	GRASS, THREE-AWN	1	NN
Artemisia ludoviciana	SAGEBRUSH,WHITE	3	NN
Asclepias spp.	MILKWEED	2	NN
Asclepias stenophylla	MILKWEED, NARROW-LEAVED	6	RSS
Asclepias syriaca	MILKWEED, COMMON	1	NN
Asclepias verticillata	MILKWEED,WHORLED	2	NN
Aster ericoides	ASTER,WHITE HEATH	4	RSS
Aster junciformis	ASTER,RUSH	9	RSS
Aster simplex	ASTER,PANICLED	2	NN
Aster sp.	ASTER, WILD	3	RSS
Astragalus crassicarpus	GROUND PLUM	7	RSS
Azolla mexicana	FERN,MEXICAN MOSQUITO	6	RSS
Bacopa rotundifolia	WATER-HYSSOP,DISK	3	RSS
Berula erecta	PARSNIP,CUT-LEAF WATER	6	RSS
Bidens cernua	BEGGAR-TICKS,NODDING	3	RSS
Bidens comosa	BEGGAR-TICKS,LEAFY-BRACT	2	NN
Bidens frondosa	BEGGAR-TICKS,DEVIL'S	1	NN
Boltonia asteroides	BOLTONIA,WHITE	3	RSS
Bouteloua curtipendula	GRAMA, SIDEOATES	5	RSS
Bouteloua gracilis	GRAMA, BLUE	4	RSS

(Sheet 1 of 6)

Table C3 (Continued)

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Bromus inermis	BROME, SMOOTH	0	EI
Bromus japonicus	BROME, JAPANESE	0	EI
Bromus tectorum	BROME, DOWNY	0	EI
Buchloe dactyloides	GRASS,BUFFALO	2	NN
Calamagrostis canadensis	REEDGRASS,BLUE-JOINT	6	RSS
Calamovilfa longifolia	PRAIRIE SANDREED	5	RSS
Callirhoe involucrata	PURPLE POPPY MALLOW	1	NN
Cannabis sativa	HEMP	0	EI
Capsella bursa-pastoris	PURSE,COMMON SHEPHERD'S	0	EI
Carduus nutans	MUSK THISTLE	0	EI
Carex brevior	SEDGE,SHORT-BEAK	3	RSS
Carex cristatella	SEDGE,CRESTED	4	RSS
Carex laeviconica	SEDGE,SMOOTH-CONE	4	RSS
Carex lanuginosa (C. pellita)	SEDGE,WOOLY	4	RSS
Carex sp.	SEDGE	4	RSS
Carex stipata	SEDGE	4	RSS
Carex tribuloides	SEDGE,BLUNT BROOM	5	RSS
Carex vulpinoidea	SEDGE,FOX	4	RSS
Celtis occidentalis	HACKBERRY,COMMON	0	EI
Cenchrus longispinus	SANDBUR	0	NN
Chenopodium album	GOOSEFOOT,WHITE	0	EI
Chenopodium desiccatum	GOOSEFOOT	4	RSS
Chenopodium pratericola (C.leptophyllum)	GOOSEFOOT, NARROW-LEAF	1	NN
Chenopodium sp	GOOSEFOOT	1	NN
Cirsium altissimum	THISTLE, ROADSIDE	0	NN
Cirsium arvense	THISTLE,CREEPING	0	EI
Cirsium canescens	THISTLE,PLATTE	4	RSS
Cirsium sp.	THISTLES	0	NN
Convolvulus spp	FIELD BINDWEED	2	EI
Convolvulus arvensis	BINDWEED, FIELD	0	EI
Conyza canadensis	HORSEWEED,CANADA	0	NN
Conyza ramosisima	SPREADING FLEABANE	0	NN
Coreopsis tinctoria	TICKSEED,GOLDEN	1	NN
Cuscuta curta (C. megalocarpa)	DODDER	5	RSS
Cyperus acuminatus	FLATSEDGE,SHORT-POINT	3	RSS
Cyperus aristatus (C. squarrosus)	FLATSEDGE, AWNED	2	NN
Cyperus erythrorhizos	FLATSEDGE,RED-ROOT	4	RSS
Cyperus esculentus	CHUFA	0	NN
Cyperus lupulinus	FLATSEDGE,HOUGHTON	1	NN
Cyperus spp.	FLATSEDGE	2	NN
Dichanthelium oligosanthes (P. oli)	WITCHGRASS,HELLER'S	5	RSS
Digitaria sanguinalis	CRABGRASS,HAIRY	0	EI
Echinochloa crusgalli	GRASS,BARNYARD	0	EI
Echinochloa muricata	GRASS,ROUGH BARNYARD	0	NN
Echinochloa spp	BARNYARD GRASS	0	NN
Eleocharis acicularis	SPIKERUSH,LEAST	4	RSS
Eleocharis compressa (E. elliptica)	SPIKERUSH, SLENDER	6	RSS

(Sheet 2 of 6)

Table C3 (Continued)

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Eleocharis erythropoda	SPIKERUSH,BALD	5	RSS
Eleocharis macrostachya (E. palustris)	SPIKERUSH,CREEPING	4	RSS
Eleocharis obtusa	SPIKERUSH,BLUNT	3	RSS
Eleocharis ovata (included in E. obtusa)	SPIKERUSH,OVATE	3	RSS
Eleocharis palustris	SPIKERUSH,CREEPING	4	RSS
Eleocharis smallii (included in E. palustris)	SPIKERUSH,SMALL'S	4	RSS
Eleocharis sp.	SPIKERUSH	4	RSS
Elymus canadensis	WILD RYE, NODDING	4	RSS
Elymus virginicus	WILD-RYE,VIRGINIA	4	RSS
Eragrostis spectabilis	LOVEGRASSS, PURPLE	3	RSS
Erigeron annuus	FLEABANE,WHITE-TOP	0	NN
Erigeron strigosus	FLEABANE,PRAIRIE	2	NN
Euphorbia cyathophora	FIRE-ON-THE-MOUNTAIN	3	RSS
Euphorbia dentata	SPURGE,TOOTHED	0	NN
Euphorbia glyptosperma	SPURGE,RIDGE-SEEDED	0	NN
Euphorbia maculata	BROOMSPURGE,SPOTTED	0	NN
Euphorbia marginata	SNOW-ON-THE-MOUNTAIN	0	NN
Euphorbia nutans	BROOMSPURGE,EYEBANE	0	NN
Fragaria virginiana	STRAWBERRY,VIRGINIA	5	RSS
Fraxinus pennsylvanica	ASH,GREEN	0	EI
Galium aparine	BEDSTRAW,CATCHWEED	0	NN
Gaura coccinea	SCARLET GAURA	4	RSS
Gleditsia triacanthos	HONEY-LOCUST	0	EI
Glyceria spp	MANNA GRASS	7	RSS
Glycine max	SOYBEAN	0	EI
Grindelia squarrosa	GUMWEED,CURLY-CUP	0	NN
Hedeoma hispidum	ROUGH FALSE PENNYROYAL	1	NN
Helianthus annuus	SUNFLOWER,COMMON	0	NN
Helianthus petiolaris	SUNFLOWER,PLAINS	0	NN
Helianthus sp	SUNFLOWER,	0	NN
Heteranthera limosa	MUD-PLANTAIN,BLUE	3	RSS
Heteranthera peduncularis (H. multiflora)	MUD-PLANTAIN	6	RSS
Heteranthera sp	MUD-PLANTAIN	4	RSS
Hordeum jubatum	BARLEY,FOX-TAIL	1	NN
Hordeum pusillum	BARLEY,LITTLE	0	NN
Juncus dudleyi	RUSH, DUDLEY	5	RSS
Juncus interior	RUSH,INLAND	4	RSS
Juncus spp.	RUSH	3	RSS
Kochia scoparia	SUMMER-CYPRESS,MEXICAN	0	EI
Kuhnia eupatorioides (Brickellia eup.)	FALSE BONESET	4	RSS
Lactuca serriola	LETTUCE,PRICKLY	0	EI
Lactuca sp	LETTUCE	0	EI
Leersia oryzoides	CUTGRASS,RICE	4	RSS
Lemna minor	DUCKWEED,LESSER	5	RSS
Lemna sp.	DUCKWEED	3	RSS
Lepidium spp.	PEPPERGRASS	1	NN
Lepidium virginicum	PEPPER-GRASS,POOR-MAN'S	0	NN

(Sheet 3 of 6)

Table C3 (Continued)

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Leptochloa fascicularis	SPRANGLE-TOP,BEARDED	1	NN
Lindernia dubia	FALSE-PIMPERNEL,YELLOW-SEED	5	RSS
Linum rigidum	FLAX,STIFFSTEM	5	RSS
Lippia cuneifolia	WEDGELEAF FOG-FRUIT	4	RSS
Lithospermum incisum	NARROW-LEAVED PUCCOON	5	RSS
Lotus purshianus (L. unifoliolatus)	TREFOIL, PRAIRIE	3	RSS
Ludwigia palustris	SEEDBOX,MARSH	5	RSS
Lycopus americanus	BUGLEWEED,AMERICAN	5	RSS
Marsilea vestita	FERN,HAIRY WATER	2	NN
Medicago sativa	ALFALFA	0	EI
Melilotus alba	SWEETCLOVER,WHITE	0	EI
Melilotus officinalis	SWEETCLOVER,YELLOW	0	EI
Mirabilis linearis	FOUR-O'CLOCK, NARROWLEAF	4	RSS
Mirabilis nyctaginea	FOUR-O'CLOCK,HEART-LEAF	0	NN
Mollugo verticillata	CARPET-WEED,GREEN	0	EI
Morus alba	MULBERRY,WHITE	0	EI
Morus rubra	MULBERRY, RED	0	EI
Muhlenbergia mexicana	MUHLY,MEXICAN	4	RSS
Muhlenbergia racemosa	MUHLY,GREEN	4	RSS
Muhlenbergia spp	MUHLY	4	RSS
Myosurus minimus	MOUSE-TAIL,TINY	2	NN
Nepeta cataria	CATNIP	0	EI
Oenothera biennis	EVENING-PRIMROSE,COMMON	1	EI
Oxalis dillenia (O. stricta)	WOODSORREL, GRAY-GREEN	0	NN
Oxalis stricta (O. fontana)	WOODSORREL,YELLOW	0	NN
Panicum capillare	WITCHGRASS	0	NN
Panicum dichotomiflorum	GRASS,FALL PANIC	0	NN
Panicum virgatum	SWITCHGRASS	4	RSS
Parietaria pensylvanica	PELLITORY,PENNSYLVANIA	0	NN
Phalaris arundinacea	GRASS,REED CANARY	0	EI
Phleum pratense	TIMOTHY	0	EI
Physalis longifolia	GROUND CHERRY,COMMON	0	NN
Physalis spp.	GROUND CHERRY	2	NN
Physalis virginiana	GROUND-CHERRY,VIRGINIA	6	RSS
Poa compressa	BLUEGRASS,CANADA	0	EI
Poa pratensis	BLUEGRASS,KENTUCKY	0	EI
Poa spp.	GRASSES	1	NN
Polygala alba	MILKWORT,WHITE	5	RSS
Polygonum amphibium (P. coccineum)	SMARTWEED,WATER	3	RSS
Polygonum arenastrum	KNOTWEED	0	EI
Polygonum bicorne (P. pensylvanicum)	SMARTWEED, PINK	0	NN
Polygonum hydropiper	SMARTWEED,SWAMP	0	EI
Polygonum lapathifolium	WILLOW-WEED	1	NN
Polygonum persicaria	THUMB,LADY'S	0	EI
Polygonum punctatum	SMARTWEED,DOTTED	3	RSS
Polygonum ramosissimum	KNOTWEED,BUSHY	2	NN
Polygonum sp1	SMARTWEED	2	NN

(Sheet 4 of 6)

Table C3 (Continued)

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Polygonum sp2	SMARTWEED	2	NN
Populus deltoides	COTTON-WOOD,EASTERN	0	EI
Portulaca oleracea	PURSLANE,COMMON	0	EI
Potamogeton gramineus	PONDWEED,GRASSY	7	RSS
Potamogeton nodosus	PONDWEED,LONG-LEAF	5	RSS
Potamogeton spp.	PONDWEED	4	RSS
Potentilla norvegica	CINQUEFOIL,NORWEGIAN	0	NN
Potentilla recta	CINQUEFOIL, SULPHUR	0	EI
Prunus americana	PLUM,AMERICAN	3	RSS
Psoralea argophylla (Pediomelum argophyllum)	SILVER-LEAF SCURFPEA	6	RSS
Psoralea tenuiflora (Psoralidium ten)	WILD ALFALFA	5	RSS
Ratibida columnifera	CONEFLOWER, PRAIRIA	4	RSS
Rhus sp	SUMAC	1	NN
Riccia fluitans	LIVERWORT	nd	nd
Riccia sp	LIVERWORT	nd	nd
Ricciocarpus sp	LIVERWORT	nd	nd
Rorippa palustris	YELLOW-CRESS,BOG	4	RSS
Rorippa sessiliflora	YELLOW-CRESS,STALKLESS	2	NN
Rorippa sinuata	YELLOW-CRESS,SPREADING	1	NN
Rorippa sp	YELLOW-CRESS	1	NN
Rosa arkansana	ROSE,PRAIRIE	4	RSS
Rumex altissimus	DOCK,PALE	0	NN
Rumex crispus	DOCK,CURLY	0	EI
Rumex spp.	DOCK	1	EI
Sagittaria calycina	ARROW-HEAD,HOODED	3	RSS
Sagittaria graminea	ARROW-HEAD,GRASS-LEAF	8	RSS
Sagittaria latifolia	ARROW-HEAD,BROAD-LEAF	5	RSS
Sagittaria longiloba	ARROW-HEAD,LONG-BARB	4	RSS
Sagittaria rigida	ARROW-HEAD,STIFF	7	RSS
Sagittaria sp	ARROWHEAD	4	RSS
Salix amygdaloides	WILLOW,PEACH-LEAF	0	EI
Schizachyrium scoparium	BLUESTEM,LITTLE	4	RSS
Scirpus acutus	BULRUSH,HARD-STEM	5	RSS
Scirpus fluviatilis	BULRUSH,RIVER	4	RSS
Scirpus heterochaetus	BULRUSH,SLENDER	4	RSS
Scirpus pungens	BULRUSH,THREE-SQUARE	4	RSS
Scirpus spp	BULRUSH	4	RSS
Scirpus validus	BULRUSH,SOFT-STEM	5	RSS
Setaria glauca	GRASS,YELLOW BRISTLE	0	EI
Setaria pumila (same as glauca)	GRASS,YELLOW BRISTLE	0	EI
Setaria sp	FOX-TAIL	0	EI
Setaria viridis	FOXTAIL, GREEN	0	EI
Silphium laciniatum	COMPASS PLANT	5	RSS
Solanum interius	NIGHTSHADE,PLAINS BLACK	1	NN
Solanum ptycanthum	NIGHTSHADE, BLACK	0	NN
Solanum rostratum	BUFFALO BUR	0	NN
Solidago canadensis	GOLDEN-ROD,CANADA	1	NN

(Sheet 5 of 6)

Table C3 (Continued)

Scientific Name	Common Name	Coefficient of Conservatism	Indicator Category
Solidago missouriensis	GOLDENROD, PRAIRIE	5	RSS
Solidago rigida	GOLDEN-ROD,STIFF	3	RSS
Solidago sp	GOLDEN-ROD	2	NN
Sorghastrum nutans	GRASS,INDIAN	5	RSS
Sorghum bicolor	MILO	0	EI
Sorghum sp	SORGHUM (CULTIVATED)	0	EI
Sparganium eurycarpum	BURREED,GIANT	5	RSS
Spartina pectinata	CORDGRASS,PRAIRIE	5	RSS
Sphaeralcea coccinea	RED FALSE MALLOW	4	RSS
Sphenopholis obtusata	WEDGEGRASS,PRAIRIE	5	RSS
Spirodela polyrhiza	DUCKWEED,GREATER	6	RSS
Sporobolus asper	DROPSEED,TALL	3	RSS
Sporobolus cryptandrus	DROPSEED,SAND	2	NN
Sporobolus vaginiflorus	DROPSEED,POVERTY	1	NN
Stachys palustris (S. pilosa var. pilosa)	HEDGENETTLE,MARSH	5	RSS
Strophostyles leiosperma	SLICK-SEED BEAN	4	RSS
Taraxacum officinale	DANDELION,COMMON	0	EI
Teucrium canadense (T. occidentale)	GERMANDER,AMERICAN	4	RSS
Thlaspi arvense	PENNY-CRESS,FIELD	0	EI
Tragopogon dubius	GOAT'S BEARD	0	EI
Tragopogon sp	GOAT'S BEARD	0	EI
Trifolium pratense	CLOVER,RED	0	EI
Trifolium repens	CLOVER,WHITE	0	EI
Triodanis perfoliata	VENUS'-LOOKING-GLASS,CLASP-LEAF	2	NN
Triticum aestivum	WHEAT (CULTIVATED)	0	EI
Typha angustifolia	CATTAIL,NARROW-LEAF	0	EI
Typha X glauca	CATTAIL, HYBRID	1	EI
Typha latifolia	CATTAIL,BROAD-LEAF	1	EI
Typha sp.	CATTAIL	1	EI
Ulmus pumila	ELM, SIBERIAN	0	EI
Utricularia vulgaris (U. macrorhiza)	BLADDERWORT,COMMON	7	RSS
Verbena bracteata	VERVAIN,PROSTRATE	0	NN
Verbena hastata	VERVAIN,BLUE	4	RSS
Verbena sp	VERVAIN,	2	NN
Verbena stricta	VERVAIN, HOARY	2	NN
Vernonia baldwinii	IRONWEED,BALDWIN'S	3	RSS
Vernonia fasciculata	IRONWEED,PRAIRIE	4	RSS
Veronica peregrina	SPEEDWELL,PURSLANE	0	NN
Vicia americana	VETCH,AMERICAN PURPLE	6	RSS
Wolffia columbiana	WATER-MEAL,COLUMBIA	7	RSS
Xanthium strumarium	COCKLE-BUR, ROUGH	0	NN
Zea mays	CORN (CULTIVATED)	0	EI

(Sheet 6 of 6)

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14. ABSTRACT

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of wetland functions at a site-specific scale. The HGM Approach was initially designed to be used in the context of the Clean Water Act, Section 404 Regulatory Program permit review to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of wetland restoration projects, and management of wetlands

This report uses the HGM Approach to develop a Regional Guidebook to (a) characterize ponded, herbaceous marshes on the loess plain of south-central Nebraska, (b) provide the rationale used to select functions of ponded, herbaceous depressional marsh subclass, (c) provide the rationale used to select model variables and metrics, (d) provide the rationale used to develop assessment models, (e) provide data from reference wetlands and document its use in calibrating model variables and assessment models, and (f) outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

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a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
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6. AUTHOR(S) and 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) (Concluded).

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15. SUBJECT TERMS (Concluded).

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